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QUATERNARY PALYNOLOGY OF THE BLUEFISH BASIN, NORTHERN YUKON TERRITORY

by

Ⓒ GEORGE H. McCOURT

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE
IN
GEOLOGY

EDMONTON, ALBERTA
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Supervisor

C R Stelck..

Charles Schweger..

Date 15th May, 1981

2

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ABSTRACT

Pollen analysis of an alluvial exposure (67° 23′ N latitude, 140° 21.5′ W longitude) along the Bluefish River, Northern Yukon Territory, provides further information on the paleoecological changes that have taken place in the interior Yukon and Alaska during the Quaternary. The sediments are all Pleistocene in age and maybe subdivided into three stratigraphic units: (1)A lower Bluefish unit, characterized by organic valley fill alluvial sediments, is thought to have been deposited prior to the Sangamon Interglacial. The basal sediments of this unit maybe earliest Pleistocene in age. (2)A middle Bluefish unit, which was not analysed for pollen, is a channel fill deposit that was probably laid down during the Sangamon Interglacial. (3)An upper Bluefish unit documents the Middle and Late Wisconsin and is represented by near shore lacustrine and deltaic sediments. A peat layer that overlies the section is considered to Holocene in age.

Two statistical analytical methods, Cluster Analysis and Principal Component Analysis, were applied to the pollen data from the Bluefish River section in an attempt to confirm the patterns that had been visually observed within the data. The results of the statistical analysis along with the visually observed results suggested the establishment of eight pollen zones.

The oldest pollen zone (BF 8) represents a pre-Illinoian Interglacial during which time the area was covered by an open spruce forest. Climatically the region experienced more precipitation and warmer temperatures than today. Prior to the onset of the Illinoian Glaciation the open forest was replaced by an open shrub-birch tundra(BF 7), rich in sedges and Artemisia A shrub-tundra also characterizes subzone BF 6b, but now Cyperaceae is the dominant ground cover. An increase in Artemisia and further reductions in the arboreal and shrub components, indicates subzone BF 6a was an open tundra. Zones BF 7 and BF 6 suggest increasingly colder temperatures and much more arid conditions. An amelioration of the climate with increased temperatures and precipitation during the time of Zone BF 5 (beginning of the Sangamon Interglacial) allowed the steppe-tundra to be replaced by a rich birch-alder shrub-tundra.

A steppe-tundra vegetation (Zone BF 4) dominated by Cyperaceae, Gramineae and Artemisia covered the region during the Middle and Late Wisconsin. The pollen spectra for Zone BF 3 indicates the vegetation was predominantly a treeless shrubless grassland. Pollen zones BF 4 and BF3 infer a climate of arctic cold and extreme aridity. A major pre-Quaternary spore zone near the top of the study section has been designated Zone BF 2. Grain size changes, slumping, reworking of sediments and variations in the pollen rain are all possible reasons for the presence of this zone. The

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pollen spectra for Zone BF 1 is very similar to the present day vegetation (Boreal Forest). Spruce is the dominant tree, with alder and birch common in the shrub layer.

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My initial interest in Palynology and subsequent involvement in this project came about as a result of many discussions with Drs. R. W. May and C. E. Schweger. Dr. May was especially helpful in teaching the author about the use of multivariate statistical methods and how they might be applied to the results of pollen analysis. Their guidance and encouragement throughout all aspects of this project is greatly appreciated.

A special thanks must go to Dr. Thelma Habgood (Paleoenvironmental Studies Laboratory, Dept. of Anthropology, University of Alberta) who devoted many hours to instructing and guiding me in the techniques of pollen analysis. Her patience and willingness in helping me identify unknown pollen grains, as well as, contributing many hours of stimulating conversation, made the tedious process of counting pollen grains much more bearable.

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Table of Contents

I Introduction 1

Objectives of Study 6

Previous Investigations 6

(a) Geology 6

(b) Paleoecology 7

II General Setting 23

Physiography 23

(a) Regional 23

(b) Porcupine Plain 25

(c) Bluefish Basin 27

Climate 28

Vegetation 31

General Pleistocene Stratigraphy 33

III Methods of Study 38

Bluefish River Study Site 38

(a) Location and Description 38

(b) Stratigraphy and Chronology 41

Field Methods 49

Laboratory Methods 53

(a) Pollen Analytical Methods 53

(b) Grain Size Analysis 55

IV Pollen Results 56

Treatment of Pollen Results 56

Surface Sample Results 56

Relative Pollen Diagrams 59

(a) Lower Bluefish Pollen Diagram 60

(b) Upper Bluefish Pollen Diagram 64

V Statistical Results 70

Treatment of Data 70

Cluster Analysis 71

(a) Lower Bluefish Unit 72

(b) Upper Bluefish Unit 76

Factor Analysis (Principal Component Analysis) 79

(a) Lower Bluefish Unit 83

(b) Upper Bluefish Unit 89

VI Interpretations and Discussion 93

Zone BF8 93

Zone BF7 98

Zone BF6 100

Zone BF5 105

Zone BF4 107

Zone BF3 110

Zone BF2 111

Zone BF1 116

VII Summary 119

References 127

Appendix A 134

Appendix B 136

Appendix C 140

Appendix D 141

Appendix E 151

Appendix F 155

Appendix G 160

Appendix H 164

Appendix I 165

University of Alberta

LIST OF TABLES

Table		Page
1	Pollen zones established by Lichti-Federovich for the Old Crow region	20
2	Climatic values for Old Crow	29
3	Stratigraphic section, south bank of Porcupine River	34
4	Stratigraphy for Bluefish River section	42
5	Surface sample pollen results	57
6	Statigraphic listing of lower Bluefish unit clusters and equivalent pollen zones	73
7	Statigraphic listing of upper Bluefish unit clusters and equivalent pollen zones	77
8	Varimax Rotated Factor Matrix lower Bluefish unit	87
9	Varimax Rotated Factor Matrix upper Bluefish unit	87
10	Habitat characterization of minor pollen taxa	104
11	Summary table of pollen zones, vegetation, stratigraphy and climate	124

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LIST OF FIGURES

Figure		Page
1	Map of Northeastern Beringia showing ice margins and glacial lakes	2
2	Map showing location of study site within the Bluefish Basin.	3
3	Phsiographic Divisions of the Northern Yukon Territory.	24
4	Old Crow Basin Composite Section	35
5	Relative Percent Pollen diagram lower Bluefish unit	pocket
6	Relative Percent Pollen diagram upper Bluefish unit	pocket
7	Group average cluster diagram for lower Bluefish unit	74
8	Group average cluster diagram for upper Bluefish unit	78
9	Factor score plot lower Bluefish unit	84
10	Factor score plot upper Bluefish unit	90
11	Grain size analysis and textural classification	111

University of Alberta

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LIST OF PLATES

Plate — Page

1(a) Alluvial section exposed by downcutting of Porcupine River 5

1(b) Study site alluvial section exposed by downcutting of Bluefish River 5

2(a) Photograph taken from the top of the Bluefish River section showing the vegetation around the study site 40

2(b) Photograph showing the vegetational zonation along the Bluefish River alluvial plain 40

3 Bluefish River study site section 45

4 Photograph showing a close up view of the relationship between the lower Bluefish Alluvial unit and the underlying coal seam and bedrock. 51

Chapter I. Introduction

The Bluefish Basin is one of three structural basin areas located in the northern Yukon Territory (Fig.1). During the Pleistocene it was part of the unglaciated Alaska - Yukon refugium (Hughes, 1972; Hopkins, 1967a, 1967b; Morlan and Matthews, 1978). As part of an extensive refugium for plants and animals (Hulten, 1937; Hopkins 1967a; Morlan, 1978), the Bluefish Basin consequently becomes very important in contributing to our understanding of the vegetational and paleoecological history of the Beringian refugium (Lichti-Federovich, 1972; Matthews, 1975). The area is located very near the modern treeline, making it a very "sensitive area for documenting past fluctuations in the Boreal biota" (Matthews, 1975:969).

The basin contains thick and extensive deposits which have been incised by the Porcupine and Bluefish Rivers (Figs. 1 and 2; Plate 1). The downcutting of these rivers has exposed large sedimentary sections up to forty metres thick, which provide a record of the Quaternary history of the region.

In an attempt to add more information for the reconstruction of the paleoecology of the Northern Yukon, an exposure along the Bluefish River (Fig. 2; Plates 1 and 2) was sampled for pollen analysis. The site designated HH - 75 - 24 by Hughes (Geological Survey of Canada), is located on

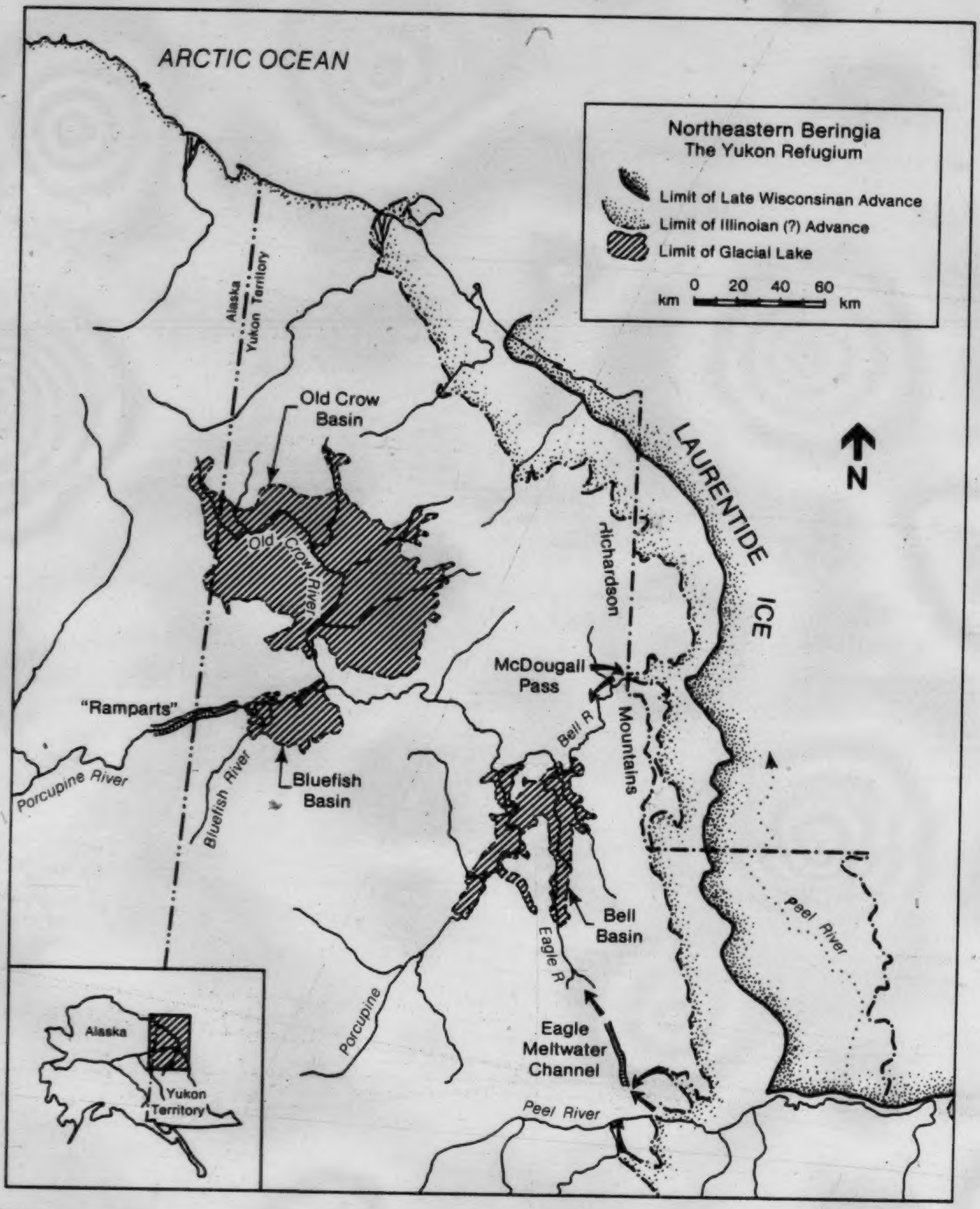
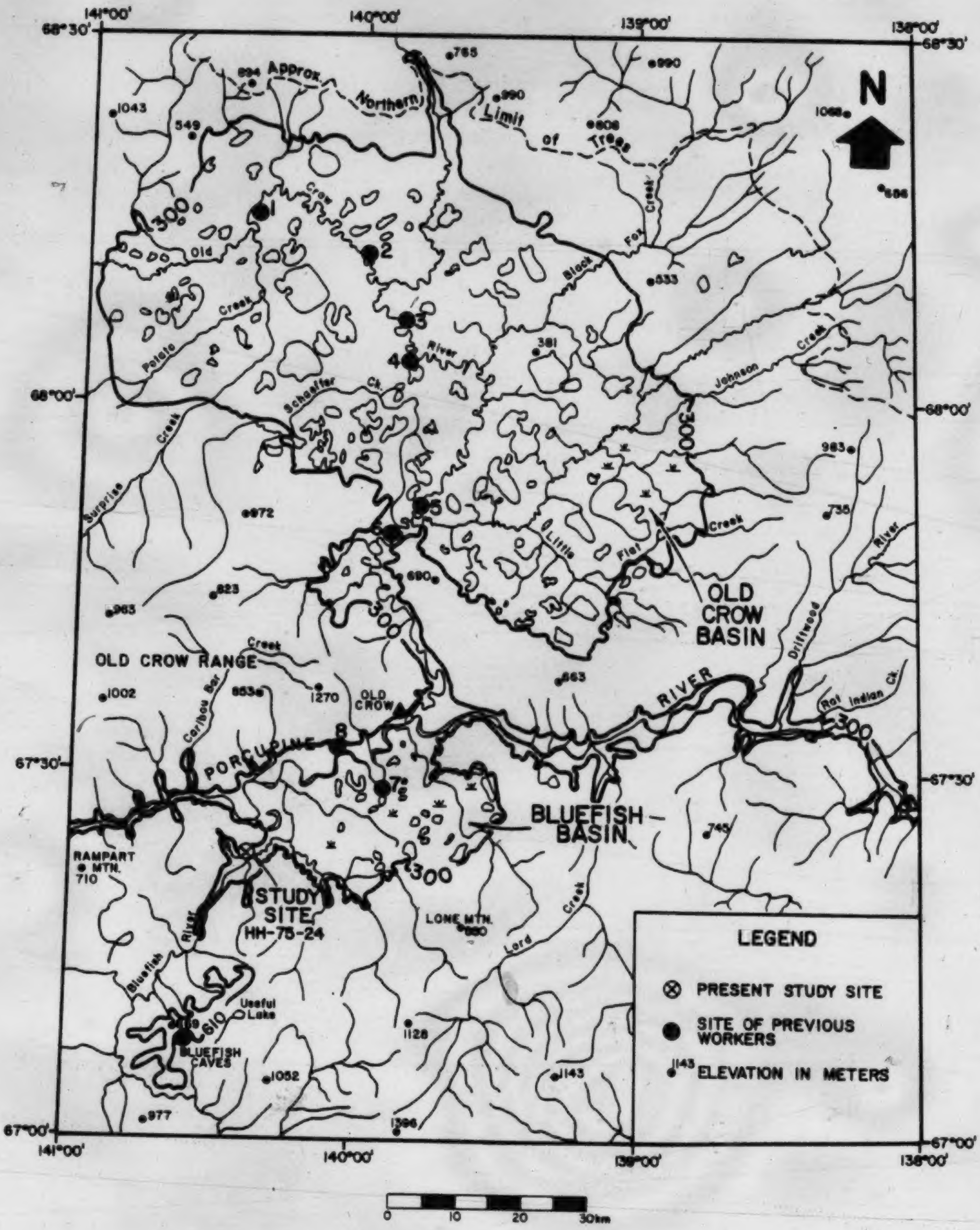

ARCTIC OCEAN
Northeastern Beringia
The Yukon Refugium
Limit of Late Wisconsinan Advance
Limit of Illinoian (?) Advance
Limit of Glacial Lake
0 20 40 60
km km
Alaska
Yukon Territory
Old Crow Basin
Old Crow River
LAURENTIDE ICE
N
Richardson
Mountains
McDougall Pass
"Ramparts"
Bell R.
Porcupine River
Bluefish River
Bluefish Basin
Bell Basin
Eagle R.
Peel River
Porcupine
Eagle Meltwater Channel
Peel River
Alaska
Yukon Territory

Figure 1: Map of Northeastern Beringia showing ice margins and glacial lake basins (taken from Morlan, 1978)



141°00'
140°00'
139°00'
138°00'
68°30'
68°00'
67°30'
67°00'
N
Approx. Northern Limit of Trees
765
894
990
990
1043
549
608
1068
686
300
1
2
3
4
5
6
7
8
Crow River
Old Crow
Potato Creek
Black
Fox Creek
633
381
Johnson Creek
Schaeffer Ck.
Surprise Creek
972
983
735
Little Flat Creek
River
680
823
963
OLD CROW BASIN
OLD CROW RANGE
Creek
Driftwood
1002
Caribou Bar
853
1270
OLD CROW
863
RIVER
Rat Indian Ck.
PORCUPINE
BLUEFISH BASIN
745
RAMPART MTN. 710
STUDY SITE HH-75-24
LONE MTN.
880
Lord Creek
Bluefish River
Useful Lake
610
1128
BLUEFISH CAVES
1052
1143
977
1396
LEGEND
⊗ PRESENT STUDY SITE
● SITE OF PREVIOUS WORKERS
1143 ELEVATION IN METERS
0
10
20
30km

Figure 2: Map showing the location of the study site within the Bluefish Basin. Study sites of previous workers mentioned in the text are also shown.

Plate 1

(a) Alluvial section exposed by downcutting of Porcupine River.

(b) Study site alluvial section exposed by downcutting of Bluefish River.

PLATE I

COLOURED PICTURES
Images en couleur

the north bank of the Bluefish River, 67° 23′ N latitude and 140° 21.5′ W longitude.

Objectives of the Study

The objectives of this study were as follows:

(1) To establish a vegetational record for the region using pollen analytical methods.

(2) To analyse the data using multivariate statistical methods to help describe the patterns within the pollen data.

(3) To attempt a paleoecological and paleoenvironmental reconstruction during the Quaternary.

Previous Investigations

The amount of published geological and paleoecological information from the Old Crow-Bluefish Region is limited.

(a) Geology

The information pertaining to the Geology of the region will only be briefly mentioned here, as it will be discussed in more detail in Chapter 2 under the heading of "Stratigraphy and Chronology".

Norris *et al.* (1963), Douglas and Maclean (1963) and Miall (1973) have outlined the general bedrock geology of the northern Yukon Territory. More detailed descriptions of the bedrock stratigraphy have been documented by Lenz (1972) and Mountjoy (1967a,1967b).

The surficial geology of the unglaciated regions, specifically the Old Crow, Bell and Bluefish Basins (Fig. 1) is known through the work of Hughes (1969,1972). In addition to the above information, these reports describe the Pleistocene stratigraphy of the Old Crow and Porcupine Rivers. Morlan (1978) and Morlan and Matthews (1980) present a composite stratigraphic section (Fig. 3) of the Old Crow Basin based on the work carried out since 1975, by the Yukon Refugium Project (see Morlan, 1978, re: Yukon Refugium Project). The Pleistocene history of the Porcupine drainage has also been described by Hughes (1969,1972) and outlined again by Morlan (1973,1978).

(b) Paleoecology

Livingstone (1955), in his pioneering pollen study from the central part of the Brooks Range, established a sequence of three pollen zones for post-glacial time in this part of northern Alaska. His pollen zones, which would later become the basic building blocks for future Quaternary paleoecological studies in the Alaska-Yukon refuguim, can be distinguished by the presence or absence of birch and other tree pollen. Pollen Zone I is characterised by high percentages of herbaceous pollen along with very small amounts of birch and other arboreal (tree) pollen. Livingstone suggests this zone represents a herbaceous vegetation which was dominated by grasses, sedges and

Artemisia. Zone II, which succeeds the herb zone, is delineated by a significant increase in percentages of birch pollen. A substantial increase in the arboreal pollen component, especially alder and spruce, marks the lower boundary of the final pollen zone (Zone III). The absence of *Alnus* and other tree pollen in Zone II leads Livingstone to suggest that the birch pollen is being derived from shrub birch as opposed to any of the tree birches. He also points out that in northern Alaska today shrub birches occupy "a latitudinal and altitudinal belt between a tundra of grasses and shrubs, and a tundra with local thickets of alder in the sheltered valleys." (Livingstone, 1955:595) The author, therefore, feels the pollen spectra for Zone II represents a shrub birch tundra. The high alder pollen frequency in Zone III is thought to represent moderate distance transport of *Alnus* pollen by wind. The pollen was probably derived from alder thickets, which were part of the regional vegetation but not present in the local vegetation (Livingstone, 1955:595). Livingstone bases his interpretation on the fact, that although alder is not present in the vicinity today, there is not a significant decline in *Alnus* pollen frequencies in the upper parts of the core. He feels these sediments were deposited as recently as 50 years ago.

Significant pollen studies have been carried out in Western Alaska by Colinvaux (1964), Matthews (1974) and Schweger (1976). Colinvaux has described a pollen core from Imuruk Lake on the Seward Peninsula.

The author believes the core contains a continuous pollen record dating as far back as the Yarmouthian, and that the vegetational history is one of a succession of different tundras, which can be broken down into three types that are very similar to those proposed by Livingstone (1955). Colinvaux suggests the "type I zones represent cold grassy tundras living in a climate as cold as the most arctic portions of modern Alaska." (1964:308) The type II zones are common during warmer climatic periods, and are dominated by dwarf birches (Livingstone's *Betula* zone) concomitant with a reduction in the amount of grass and the beginning of the development of grass tussocks. He further states that during the warmest climatic intervals, which includes the present day climate, there is widespread development of grass tussock tundra. An increase in the arboreal pollen component especially spruce and alder, suggests that the climatic conditions were warm enough to allow the treeline to advance into the region. This pollen spectra makes up the tundra that characterizes Zone III.

Following this scheme Colinvaux suggests that during the Yarmouthian Interglacial the vegetation was characterized by shrub birch tundra (Zone II) and grass-tussock tundra (Zone III). The subsequent deterioration of the climate and the resulting Illinoian Glaciation gave rise to an "extreme version" of Zone I type vegetation, where there is only a trace of *Betula* pollen, otherwise the pollen spectra is completely dominated by the herbaceous pollen component. Following the Illinoian Glaciation there is a reappearance of the tussock-tundra (Zone III) which Colinvaux feels is representative of the Sangamon Interglacial. With the onset of the Wisconsin Glaciation the vegetation reverts back to a herbaceous tundra (Zone I) which is very similar to the tundra that developed during the Illinoian Glaciation. The post glacial vegetational history is similar to that outlined by Livingstone with the herbaceous tundra being replaced by the shrub birch tundra (Zone II) which in turn is succeeded by the tussock-tundra (Zone III).

Matthews (1974a) has analysed sediments taken from a colluvial section at Cape Deceit, Alaska. The section is located to the north of the Imuruk Lake study site (Colinvaux, 1964) and the sediments are thought to range in age from latest early Pleistocene to the Holocene. The sediments from the basal part of the section are considered to be Cromerian (400,000 - 900,000) in age and document a series of glacial-interglacial events that occurred in the region during this time. The pollen record, for Cromerian time, shows that during the glacial intervals the area was dominated by a shrub or steppe-tundra type of vegetation. The interglacial intervals are characterized by the presence of a forest or forest tundra type of vegetation. During the pre-Illinoian interglacial the Cape Deceit region was covered by an open spruce forest. This was replaced by a herbaceous tundra, at the beginning of the Illinoian

Glaciation. The Sangamon Interglacial is marked by the appearance of a shrub birch tundra, which was probably very similar to the present day vegetation. The author feels that alder was also fairly abundant in the valley areas during this time.

With the onset of the Early Wisconsin Glaciation the shrub birch tundra was succeeded by herbaceous tundra characterized by the presence of grasses, *Potentilla* and Cruciferae. Around 12,000 - 13,000 years ago the study area was reinvaded by a steppe tundra with grasses, *Artemisia* and *Potentilla* abundant in the local vegetation. The warming of the climate during the Early Holocene allowed the replacement of the steppe-tundra with a shrub birch tundra. The Late Holocene is marked by the appearance of alders in the river valleys and the spreading of dwarf birch to form a tundra that is still present today.

Schweger (1976) has documented a fossil pollen record from Onion Portage region of the Kobuk River valley in northwestern Alaska. The river has eroded down through sequences of valley colluvium exposing excellent Pleistocene stratigraphic sections. The organic rich sediments collected from these exposures have yielded a pollen record that outlines the vegetational history of the region since the Middle Wisconsin Interstadial. The Kobuk River section shows a Middle Wisconsin fossil pollen record that is characterized by grasses, sedge and *Artemisia*. Schweger suggests this record indicates a steppe-tundra vegetation. During the Late Wisconsin Glaciation the fossil pollen history indicates the presence of a sedge-herbaceous tundra that is dominated by Cyperaceae pollen as well as lesser amounts of grass and *Artmeisia* pollen. Around 11,000 B.P., following the retreat of the Late Wisconsin glaciers, the Onion Portage area was invaded by shrub birch forming a shrub-tundra vegetation. The continued trend toward a warmer climate, along with an increase in moisture eventually resulted in the appearance of alder around 7,000 B.P. The arrival of spruce approximately 5,700 years ago established the forest-tundra vegetation that is still present in the area today.

The most significant paleobotanical studies from interior Alaska have been carried out by Matthews (1974b) and Ager (1975). Matthews, using both pollen analysis and plant macrofossils (mainly seeds and insects), analysed a 27 meter core taken from pereniallly-frozen valley fill in the Isabella Basin, near Fairbanks. His study provides the longest record of Late Quaternary vegetational history for the interior of Alaska, spanning about 35,000 years. Zone A (35,000 - 32,000 B.P.) is characterized by relatively high percentages of *Picea* and low percentages of *Artemesia*, and is considered to be representative of the Middle Wisconsin Interstadial. This zone has been subdivided by Matthews into two subzones based on differences in percentages of *Betula*, *Alnus* and Cyperaceae. The author suggests, that during subzone Ab time, the lower portion of the Isabella Basin was characterized by an open, sedge-dominated, environment with scattered spruce and practically no alders. Dwarf birch was also present at this time. The appearance of alder and an increased tree cover (spruce and arboreal birches) in the lower part of the basin describe the vegetational changes that occurred during the time of subzone Aa. Matthews also feels that the treeline was at a higher elevation in the basin at this time. Plant and animal macrofossils from this zone indicate a pond or lake was present near the core site and in fact "marsh inhabiting sedges and grasses must have grown quite near the site." (Matthews, 1974:836)

Very low percentages of *Alnus* and *Picea* and high percentages of Cyperaceae and *Artemisia* suggest that "zone B represents a Late Wisconsin interval of severe arctic climate." (1974b:828) It appears that many of the forests disappeared from interior Alaska and the region became dominated by a steppe-tundra vegetation. Matthews documents a slight increase in *Betula* pollen near the top of zone B and he says this represents an amelioration of the climate around 12,000 years ago. By 8,500 B.P. climatic conditions were warm enough to allow the return of spruce-deciduous forest to the lowlands of the Fairbanks area. The vegetation has shown little change over the last 8,500 years.

The work of Ager (1975) has further supplemented the Late Quaternary vegetational history of interior Alaska as outlined by Matthews (1974a). Ager analysed cores taken from three lakes and a peat bog in the middle Tanana Valley and was able to provide a record of vegetational changes that spanned the last 16,000 years. In his report, Ager suggests, that during the full glacial conditions of the Late Wisconsin until about 14,000 years ago, the region was occupied by a steppe-tundra vegetation. The steppe-tundra was characterized by grasses, *Artemisia*, some sedges and a number of "opportunistic" herbs. (1975:87) This he feels is indicative of a considerably drier and cooler climate than exists in the region today. Around 14,000 years ago there was a climatic change to warmer and moister conditions, and the steppe-tundra vegetation was replaced by a shrub-tundra. The shrub-tundra was probably composed of shrub birch, willows, sedges, grasses and heaths. (1975:87) The pollen record suggests that *Picea* and other trees began to invade the region about 10,000 years ago and spruce-paper birch forests were probably well established in the area by about 9,000 years B.P.. Ager is uncertain as to whether the spruce arrived from some distant refugium or "a few scattered spruce did survive in or near the Tanana Valley during the Late Wisconsin Glaciation and expanded their range immediately when climatic conditions allowed." (Ager, 1975:abstract) The last 8,400 years is marked by an appearance of alder which "has been an important component of the regional vegetation" for the past 8,000 years (Ager, 1975:88). There is also a decrease in spruce pollen until about 7,000 years ago indicating a decline in the spruce forests. Ager feels that increased forest fire activity, as a result of warmer and drier climatic conditions, may have been the cause. He notes that disease may also have been a factor in the spruce decline. The pollen record for the past 6,500 years suggests that there has been little change in the major plant taxa present during that interval.

The first significant pollen record to be established for the Yukon Territory was documented in the study carried out by Terasmae and Hughes (1966). The authors analysed cores taken from two lakes located in the western Ogilvie Mountains. The vegetational history put forward by Terasmae and Hughes is very similar to the pollen record outlined by Livingstone (1955) for northern Alaska. In their study they describe three pollen zones which outline the succession of vegetational changes that have taken palce in this part of the Yukon over the last 14,000 years. Zone I is characterized by the abundance of Cyperaceae pollen and is probably representative of a herbaceous tundra type vegetation. Around 11,000 - 12,000 years ago there is a marked increase in *Betula* pollen (Zone II) indicating the invasion of the region by shrub birch. The lower boundary of Zone III (8,000 B.P.) is marked by a significant increase of spruce and alder pollen. The pollen spectra from this zone suggest that spruce and alder have become a significant part of the regional vegetation.

A pollen record spanning the past 31,000 years was obtained by Rampton (1971a) from Antifreeze Pond in the Snag-Klutlan area of southwestern Yukon. The Antifreeze Pond pollen history is of particular interest because it was the first pollen record to span all of the Late Wisconsin and Holocene time.

Rampton's study shows that between 31,000 and 27,000 B.P. the area was first covered by a fell-field or sedge-moss tundra (zone 1) followed by a shrub-tundra (zone 2). The shrub-tundra was characterized by the presence of shrub birch, although Rampton points out the herbaceous pollen component is almost as abundant as it was in zone 1 (1971a:976). The area was once again covered by a sedge-moss tundra (zone 3) after 27,000 B.P. and it remained in the region until 10,000 B.P. The pollen spectra for this zone is very similar to other sedge-moss tundras that are thought to have existed in other parts of Alaska and the Yukon during the Middle Wisconsin (Livingstone, 1955; Colinvaux, 1964; Lichti-Federovich, 1972,1974;Ager, 1975). The author feels that around 13,500 B.P. there was a slight change in either climatic or limnological conditions allowing the development of aquatic vegetation (Rampton, 1971a:976). Cyperaceae also increased in importance relative to grasses (1971a:976). The amelioration of the climate that coincided with the Late Wisconsin ice retreat (10,000 B.P.) allowed the landscape to be reinvaded by shrub birch tundra (zone 4). This zone is also very similar to post-glacial shrub birch pollen zones that have been documented in this part of northwestern North America (Livingstone, 1955; Colinvaux, 1964; Lichti-Federovich, 1972,1974; Ager, 1975; Schweger, 1976). Approximately 8,700 years ago the Snag-Klutlan area became covered by a spruce woodland (zone 5) indicating a futher warming of the climate. The arrival of alder about 5,700 years ago, along with the continued presence of spruce and birch established the spruce forest vegetation (zone 6) that still exists in the region today.

Matthews (1975) has described insect fossils and plant macrofossils from two exposures in the Old Crow-Porcupine region. One of the exposures (Site 8, Fig. 2), which is located on the Porcupine River, contains a fossil assemblage dated to be around 32,000 ± 770 years old. The other assemblage of fossils comes from a site (Site 2, Fig. 2) in the Old Crow Basin, and is thought to be older than 44,000 years. This date is based on a 14C date of > 44,000 years obtained from a piece of wood near the base of the unit overlying the fossil assemblage. In his report, Matthews suggests that each site was located in a forest-tundra vegetation during the time the fossil assemblages were being laid down. He proposes, however, that the climatic conditions of the region were considerably different at the time of deposition at each site. Matthews feels that the Porcupine River assemblage contains more tundra species of plants and insects, and this implies a colder climate than at present. The colder climate probably also meant a retreat of the treeline to the south, so that the Old Crow Basin, which today contains a forest tundra vegetation, would have been totally treeless. The Old Crow assemblage, which consists of many species that are found today within the treeline, probably indicates climatic conditions that were fairly similar to those of today.

The classification and paleoecological interpretation of a large collection of vertebrate fossils from numerous localities in the Old Crow region have been documented in a number of articles by Harrington (1970,1971,1974). The fossil evidence leads Harrington to suggest that the Middle Wisconsin environment of the Old Crow Basin consisted of "extensive grassy uplands, with spruce woodland, lakes and sluggish streams in the lower areas," (Harrington, 1971:81) and the climatic conditions were probably quite similar to those found in the region today.

Fossil pollen data from the Northern Yukon is very scarce, with only three published reports from the area. Lichti-Federovich (1972,1974) has analysed samples from six exposures (Sites 1 to 6, Fig. 2), along the Old Crow River and two exposures along the Porcupine River (Sites 7 and 8, Fig. 2). The age of these exposures is presently in a state of flux because at the present there is very little dating or stratigraphic control. The base of the Porcupine River exposures, which are considered to be the older of the two areas, is generally thought to be Sangamon in age or older.

It should be mentioned that a magnetic reversal has been discovered by Westgate (University of Toronto) in a glaciolacustrine unit (see Table 3; Unit 3), which lies just above the base of the Porcupine River sections(Schweger, personal communication).

The magnetic reversal might be part of the Matuyama Reversed Epoch, which is thought to have lasted from 2.47 m.y. ago (Late Pliocene) until 0.73 m.y. ago (Early Pleistocene) (Berggren et al, 1980). However, there are also a number of reversed events that occur in the Gauss Normal Epoch (3.4 m.y. to 2.4 m.y.) as well as one reversed event (the Laschamp Event) that occurs within the Brunhes Normal Epoch (0.73 m.y. to the present)(Berggren et al, 1980). Unfortunately, it is very difficult to pin-point which magnetic reversal is represented in the Porcupine River section, because as previously mentioned, there is very little geochronologic control for this section.

Lichti-Federovich encountered a number of problems during her analysis of the pollen samples. Many samples were sterile, pollen preservation was very poor, and she found it neccessary therefore to count a large number of slides in order to get an adequate pollen sum. Lichti-Federovich perservered to establish a pollen record for the area, and was able to distinguish five major pollen zones within the pollen diagrams. The pollen zones and the percentages of the major pollen types within each zone are shown in Table 1.

TABLE 1: Pollen zones established by Lichti - Federovich (1972,1974) for Old Crow region(youngest zone at top)

Zone I	*Picea* - *Betula* - *Alnus* - Ericad	Alnus (30-50%) *Betula* (20-25%) *Picea* (10-20%) Ericads (5%)	Modern vegetation; Boreal forest
Zone II	*Picea* - *Betula* - Glumiflorae - Herb	*Picea* (±30%) *Betula* (±25%) Glumiflorae (Cyperaceae 7-20%) (Gramineae 20-25%) Rich herb Component	Forest tundra
Zone III	Glumiflorae - Herb	Glumiflorae (Gyperaceae and Gramineae 40-75%) Rich herb component	Treeless Glumiforae herb tundra
Zone IV	*Betula* - Herb	*Betula* (>50%) Glumiflorae (±30%) *Picea* (±10%) *Alnus* (±10%) Sparce herb component.	Treeless dwarf birch tundra.
Zone Vb	*Pinus* - *Picea* - *Betula*	*Pinus* (20-50%) *Picea* (10-20%) *Betula* (30-45%)	Open pine-spruce birch forest; herb dominated treeless community open area.
Zone Va	*Betula* - *Pinus* - *Picea* - *Corylus*	*Betula* (30-50%) *Pinus* (10-40%) *Corylus* (3-5%)	Spruce pine birch forest; alder common locally; hazel occurs sporadically.

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Lichti-Federovich suggests that zones Va and Vb are representative of the vegetation that existed in the area during a pre-Wisconsin Interglacial. She envisions a spruce-pine-birch forest (Zone Va) with alder common locally and hazel occurring sporadically thoughout the area. This was replaced by an open pine-spruce-birch forest (Zone Vb) with a herb dominated treeless community in the open areas. Immediately before the Early Wisconsin Glaciation the forest zone was replaced by a tundra landscape.

Following the Early Wisconsin Stadial the region was occupied by a treeless, tundra type vegetation which was either a Glumiflorae - herb tundra (Zone III) or a dwarf birch tundra (Zone IV). This was succeeded by a forest tundra (Zone II), which was replaced just before the last glacial event by another treeless - tundra vegetation (Zone III). The post glacial vegetational history of the region is expressed by Zone 1, which is very similar to the modern vegetation.

Cinq-Mars (1979) has reported on Bluefish Cave a late Pleistocene cave along the upper middle course of the Bluefish River (see Bluefish Caves, Fig. 2). In his report, Cinq-Mars documents a preliminary summary pollen diagram based on the analysis of the cave sediments by L. Cwynar(U. of Toronto). The pollen diagram is divided into three zones, oldest to youngest, as follows:

Zone I - characterized by a predominance of Gramineae, *Artemisia* , Cyperacae and Tubuliflorae pollen.

Zone II - characterized by a relative decrease in the above pollen types as *Betula* percentages rise ((Cwynar feels that dwarf birch (*B. glandulosa* - *B. nana*) is responsible for the pollen)).

Zone III - characterized by a *Picea* percentage rise, followed by an *Alnus* percentage rise.

The base of the diagram (Zone I) is dated at 10,000-14,000 B.P. The record established shows a vegetational succession from herbaceous tundra to shrub birch tundra and finally the establishment of the boreal forest.

Chapter II. General Setting

Physiography

(a) Regional

The physiography of the northern Yukon has been described by Bostock (1948) and the following outline of the general physiography of the region is taken from his report.

The Bluefish Basin is part of a much larger physiographic unit known as the Porcupine Plain (Fig. 3). The Plain itself is bounded by the British Mountains to the north, the Old Crow Range and the Porcupine Plateau (this includes the Keele Range) to the west and south and by the Richardson Mountains to the east (see Fig. 3). The British Mountains (Fig. 3), which are the eastern extension of the Alaskan Brooks Range, are an east-west trending group of mountain ridges characterized by summits of more than 1,600 meters and very deep V-shaped valleys. They are comprised primarily of Mesozoic and Paleozoic shales and limestones. The Old Crow Range (Fig. 3), formed during the Caledonian Orogeny, stands a few miles back from the north side of the Porcupine River, and is basically a granitic mass with elevations around 1,000 meters. The Porcupine Plateau, composed predominantly of Paleozoic shales, is an area of rolling widely spaced hills with a relief of more than 300 meters. The surface of the Plateau is characterized by broad flat tops, which are remnants of a former erosion surface.

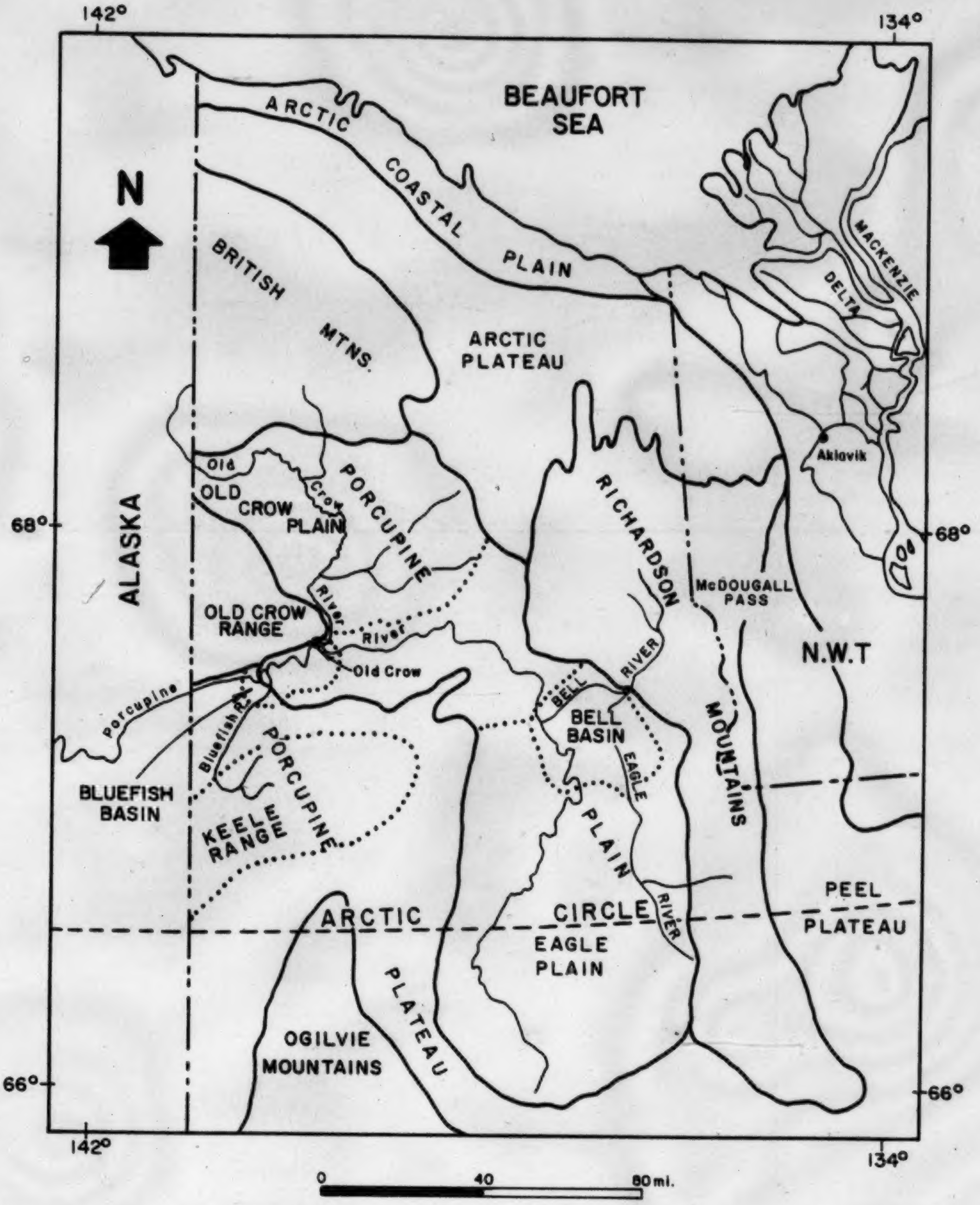
142°
134°
BEAUFORT SEA
N
ARCTIC COASTAL PLAIN
BRITISH MTNS.
ARCTIC PLATEAU
MACKENZIE DELTA
Aklavik
Old
OLD CROW PLAIN
Crow
PORCUPINE
RICHARDSON
ALASKA
68°
McDOUGALL PASS
OLD CROW RANGE
River
River
Old Crow
N.W.T
Porcupine
Bluefish R.
BELL RIVER
BELL BASIN
EAGLE
PORCUPINE
MOUNTAINS
BLUEFISH BASIN
KEELE RANGE
PLAIN
ARCTIC CIRCLE
RIVER
PEEL PLATEAU
EAGLE PLAIN
PLATEAU
OGILVIE MOUNTAINS
66°
0
40
80 mi.

Figure 3: Physiographic Divisions of the Northern Yukon Territory

The Keele Range is a small area of higher plateaus with the highest ridges 1,500 metres above mean sea level.

The Richardson Mountains (Fig. 3) form a relatively straight and narrow north-south trending barrier except for the north end which is considerably broader. The north half of the range is composed of Jurassic shales, sandstones and conglomerates and was described as having "rugged sharp ridges, steep rocky slopes and spurs separated by deep V-shaped valleys" (Bostock, 1948:35). Cretaceous sediments (shales, sandstones and conglomerates) make up the southern half of the mountains which have steep smooth slopes, and only a few rough outcrops.

(b) Porcupine Plain

The Porcupine Plain (Fig. 3) is a long shallow depression which can be subdivided into four smaller physiographic regions. In the southern half of the plain are the Bell Basin and the Eagle Plain (Fig. 3). The Old Crow Basin (also called the Old Crow Plain) occupies the northern portion of the Porcupine Plain (see Fig. 3), while the Bluefish Basin is situated southwest of the Old Crow Basin (Figs. 1 and 2).

The Eagle Plain (Fig. 3) is shaped like a square tray with low rounded edges. The surface of the plain is tilted downward to the north where the Bell Basin fills its lowest part. The south central higher parts are dissected by branching streams that have entrenched their valleys in a spreading dendritic pattern extending back from the north flowing Porcupine and Eagle Rivers.

The Bell Basin (Figs. 1 and 3) is a low area 40 to 50 kilometers in diameter and is centered around the junctions of the Eagle, Bell and Porcupine Rivers. Its relatively flat surface is dotted with ponds, lakes and swamps. The river valleys are approximately 270 meters deep in the Eagle Plain but decline to less than 30 meters in the Bell Basin. The bedrock underlying the Eagle Plain and the Bell Basin is primarily Paleozoic quartzites, Cretaceous and Tertiary shales and sandstones.

The Old Crow Basin covers 6,500 square kilometers and lies below the 300 meter elevation mark. It is

> "a great flat area thickly spotted with lakes and ponds that occupy probably more than 30 percent of its surface, but end around the borders of the plain where the ground rises towards the hills... Some of the larger lakes are known to be very shallow and this is believed to be true of most of them. Old Crow River and its main tributaries meander elaborately in valleys entrenched 20 to 30 meters below the level of the plain on which the lakes lie (Bostock, 1948:76)

The basin is predominantly filled with Late Cretaceous to Cenozoic unconsolidated deposits with inliers of Paleozoic rocks.

(c) Bluefish Basin

The Bluefish Basin (Figs. 1 and 2) being connected is for the most part similar to the previously described Old Crow Basin. The basin is not as large (1,000 square kilometers), but like the Old Crow Basin lies below the 300 meter elevation mark and is dotted with thermokarst lakes. Its northern boundary is delineated by the Porcupine River and it extends east-west from approximately the junction of the Old Crow River and the Porcupine River to an area of deeply incised bedrock known as the Ramparts (see Fig. 1). The Porcupine Plateau marks its southern limit. The basin is cut by two rivers: (1) the Porcupine which runs approximately east-west and (2) the Bluefish River, which arises in the Keele Range to the south and flows in a northeasterly direction until it meets the Porcupine River about 20 kilometers southwest of the native settlement of Old Crow (Fig. 2).

Hughes (1972), has noted that the "sediments in the Old Crow and Bluefish Basins, and probably those in the Bell Basin, extend below the bedrock thresholds of the respective basins. The basins, therefore cannot be entirely erosional, and Tertiary or early Pleistocene warping or faulting must have contributed to their origin" (Hughes, 1972:6).

Climate

The only climatic data for the Old Crow region comes from a somewhat fragmentary record from the settlement of Old Crow. However, there is enough data available between 1952 and 1979 to be able to give a general idea of the yearly temperature variation, amount of precipitation and number of frost free days (Table 2).

The northern Yukon is affected by three major types of air masses (Kendrew and Kerr, 1953). In the winter months, maritime arctic and maritime polar air masses are dominant with the continental air mass not all that uncommon. The continental arctic air mass does occasionally form in the Yukon and can also come in from the Northwest Territories when a steep barometric gradient overcomes the defensive line of the Mackenzie and Richardson Mountains. In the summer, maritime arctic and maritime tropical air masses can be present.

The climate of the area can be classified as continental with wide extremes of temperature (-33.7 ° C mean for January; 14.1 ° C mean for July) and relatively little precipitation (212 mm per year). The high relief to the southwest, south and southeast (St. Elias Ranges, Ogilvie and Mackenzie Mountains) is responsible for the dryness of the study area. These ranges act as a barrier to much of the moisture that would be carried in from the Gulf of Alaska. The little precipitation the region gets is

TABLE 2: Climatic values for Old Crow (1952-1979)
(Atmospheric Enviromental Services)

TEMPERATURE(°C)	Jan	Apr	May	June	July	Aug	Oct
Mean Daily Maximum	-28.8	-5.5	6.5	18.2	20.7	16.1	-4.9
Mean Daily Minimum	-38.6	-17.9	-4.2	5.9	7.5	4.6	-12.8
Mean Daily	-33.7	-11.7	1.2	12.0	14.1	10.4	-8.8
Extreme Maximum	-0.6	15.0	23.9	30.6	30.5	30.0	12.8
(Day/Date)	(5/74)	(29/79)	(31/53)	(16/19)	(25/79)	(5/77)	(7/69)
Extreme Minimum	-59.4	-39.4	-20.0	-8.3	-2.5	-6.7	-37.2
(Day/Date)	(5/75)	(1/71)	(3/74)	(1/69)	(1/77)	(24/74)	(31/53)
PRECIPITATION							
Mean Rainfall(mm)	NIL	NIL	4.0	32.1	22.1	37.3	1.9
Mean Snowfall(cm)	9.1	6.2	4.9	TR	TR	1.0	24.1
Mean Total(mm)	9.1	6.2	8.9	32.1	22.1	38.3	26.0
Number of Days with measureable rainfall	NIL	NIL	1	4	5	7	2
Number of Days with measureable snowfall	4	3	3	1	NIL	1	6
Number of Days with measureable precipitation	4	3	4	5	5	8	8
-Maximum Total(mm)	14.7	25.1	40.6	154.4	53.8	97.0	61.7
(year)	(77)	(52)	(76)	(56)	(55)	(69)	74
-Minimum Total(mm)	2.3	NIL	1.0	TR	4.3	0.2	19.1
(year)	(72)	(56)	(54)	(71)	(76)	(77)	(79)
Mean Month End Depth of Snow on Ground(cm)	45	30	TR	NIL	NIL	NIL	16
Number of Days with Frost	31	30	24	4	1	5	31

Greatest rainfall - 58.4mm on 21 June, 1956
Greatest snowfall - 2.3cm on 17 October, 1954

Greatest Total Monthly Rainfall - 154.3 mm (June, 1956)
Greatest Total Monthly Snowfall - 19.1 cm (October, 1979)

University of Alberta

primarily a result of uplifted troughs (occluded depressions) filled with warm air (usually maritime polar) being transported from the west across continental Alaska. As these trowels or troughs approach the area, there is a drop in air pressure and low cloud forms covering the sky. This usually results in some form of precipitation.

On the average there are only 71 days per year with a measurable precipitation. The average total measurable precipitation is less that 10 cm and the area can therefore be called arid. June and July are the only months when mean snowfall is so small that it is not worth measuring, although from the beginning of May until the end of September the mean month end depth of snow does not accumulate above the trace level. There are only 96 frost free days per year and they occur primarily during the months of June, July and August.

There has been no information gathered concerning wind speed and predominant wind direction. Morlan (1973) does mention, however, that he has observed during the summer months "generally easterly and westerly winds, paralleling the trend of the middle Porcupine Valley" (page 30). He also notes that the winter months are characterized by "cold northerly prevailing winds" (page 30).

Vegetation

There are very few detailed accounts of the vegetation of the Old Crow region, which includes the Bluefish Basin. Welsh and Rigby (1971), Hettinger *et al.* (1973) and Oswald and Senyk (1977) have all outlined the general vegetation of the northern Yukon. Drew and Shanks (1965) have described the forest - tundra vegetation 100 kilometres northwest of the study area but the vegetation of this area is quite different from the vegetation observed in the Bluefish Basin. The most detailed study of the flora of the Old Crow region has been carried out by Cwyner (1977, unpublished data). The following general account of the vegetation of the Bluefish Basin is primarily from my own observations along the Bluefish River and at the study site. A list of species collected from the study site is given in Appendix A. The nomenclature used to identify plants follows that of Hulten (1968).

Although the region lies within the limit of the northern treeline it is classified as forest and barren (Rowe, 1972) or parkland tundra-taiga (Welsh and Rigby, 1971) because the tree cover is very localized. The scarcity of trees is probably related to a number of factors including poor drainage within the basin areas, a cool, dry, summer climate and the presence of a continuous permafrost layer, although the permafrost is often encountered fairly deep below the surface in places.

In the forest regions, white spruce (*Picea glauca*) is usually found at the better drained sites (*eg.* floodplains), as well as on south facing slopes. North facing slopes and poorly drained areas are dominated by black spruce (*Picea mariana*). Quaking aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera* L. subsp. *balsamifera*) as well as paper birch (*Betula papyrifera*) are commonly found on river terraces, alluvial flats and river gravel bars, but are abundant only in early successional stands following disturbances, primarily fire (Oswald and Senyk, 1971:71). The gravel bars tend to show a form of vegetational zonation, with willows (*Salix* spp.) found closest to the rivers, followed by poplars (*Populus* spp.), which in turn are succeeded by stands of spruce (usually *Picea glauca*).

The shrub layer is generally poorly developed, but can form extensive thickets in openings and under trees. It is dominated by dwarf birch (*Betula nana*), shrub birch (B. *glandulosa*), mountain alder (*Alnus crispa* L. subsp. *crispa*) and a variety of willows (*Salix* spp.). Soapberry (*Shepherdia canadensis*), prickly rose (*Rosa acicularis*) and shrubby cinque foil (*Potentilla fruticosa*) are also present.

The ground cover is quite variable because it is dependant on how well or how poorly the sites are drained. The drier sites are represented by species such as sedges (*Carex capillaris*, C. *scirpoides*), horsetail (*Equisetum scirpoides*), bearberry (*Arctostaphylos rubra*), false

Asphodel (*Toefieldia coccinea*), and the composite *Saussurea angustifolia*. The more poorly drained areas are dominated by the ericads. These include Labrador tea (*Ledum palustre* L. subsp. *groenlandicum*), alpine blueberry (*Vaccinium uliginosum*), and Lingonberry (*Vaccinium vitis-idaea*). *Sphagnum* spp. and *Hylocomuim splendens* are the most common mosses. *Eriophorum vaginatum* (Hare's-Tail Grass) is the predominant sedge, with *Rubus chamaemorus* (Cloudberry) and *Petasities frigidus* being the most abundant herbs. The open areas between the tree stands are characterized, for the most part, by the same species composition as the treed areas.

The tundra areas, which become quite common as you move away from the lakes and streams, can be classified as tussock or heath tundra. The tussocks are usually hummocky and are composed chiefly of *Eriophorum vaginatum* (Hare's-Tail Grass) or heaths, with dwarf birch (*Betula nana*) and alder also being present in smaller quantities. *Sphagnum* sp. often grows on the sides or between hummocks (Oswald and Senyk, 1971:71).

General Pleistocene Stratigraphy

The entire Porcupine Plain was unglaciated, although ice advances from the east had a direct bearing on many of the deposits being laid down in the three basinal areas. Prior to any advance of Laurentide ice, the drainage of the region was probably to the east and northeast through the

McDougall Pass (Fig. 1) in the Richardson Mountains (Hughes, 1972). During this time (possibly pre-Illinoian) the basins were being filled with fluviatile and deltaic deposits (Units 1 and 2 in Table 3). With the first recognized Laurentide ice advance the drainage to the east was dammed. According to Morlan and Matthews (1978):

> water of these streams, augmented by meltwater from the glacial front itself was diverted to the west through McDougall Pass into the Bell Valley across the low divide between Peel River and the head of the Eagle Valley (p. 3).

These waters accumulated in the Bell, Bluefish and Old Crow Basins, and were eventually discharged westward through the Ramparts (Fig. 1). Inorganic glaciolacustrine clays were deposited in these lakes (Unit 3 from Table 3; Unit 1 from Fig. 4). Studies of vertebrates, insects and plant macrofossils (Morlan and Matthews, 1978:3) suggest that the glaciolacustrine clays from the Old Crow Basin might be Illinoian in age. The age of the first glaciolacustrine clays deposited in the Bluefish Basin are still subject to debate, and they might possibly be as old as the Matuyama reversal (Schweger, personal communication).

With the retreat of the Laurentide ice the drainage was re-established to the east and the basins were once again infilled with deltaic, fluvial and alluvial sediments (Units 4 and 5, Table 3; Units 3a,b,c,4,5 in Fig. 4). A second Laurentide ice advance again dammed the drainage to the east causing the basins to refill and eventually discharge to the

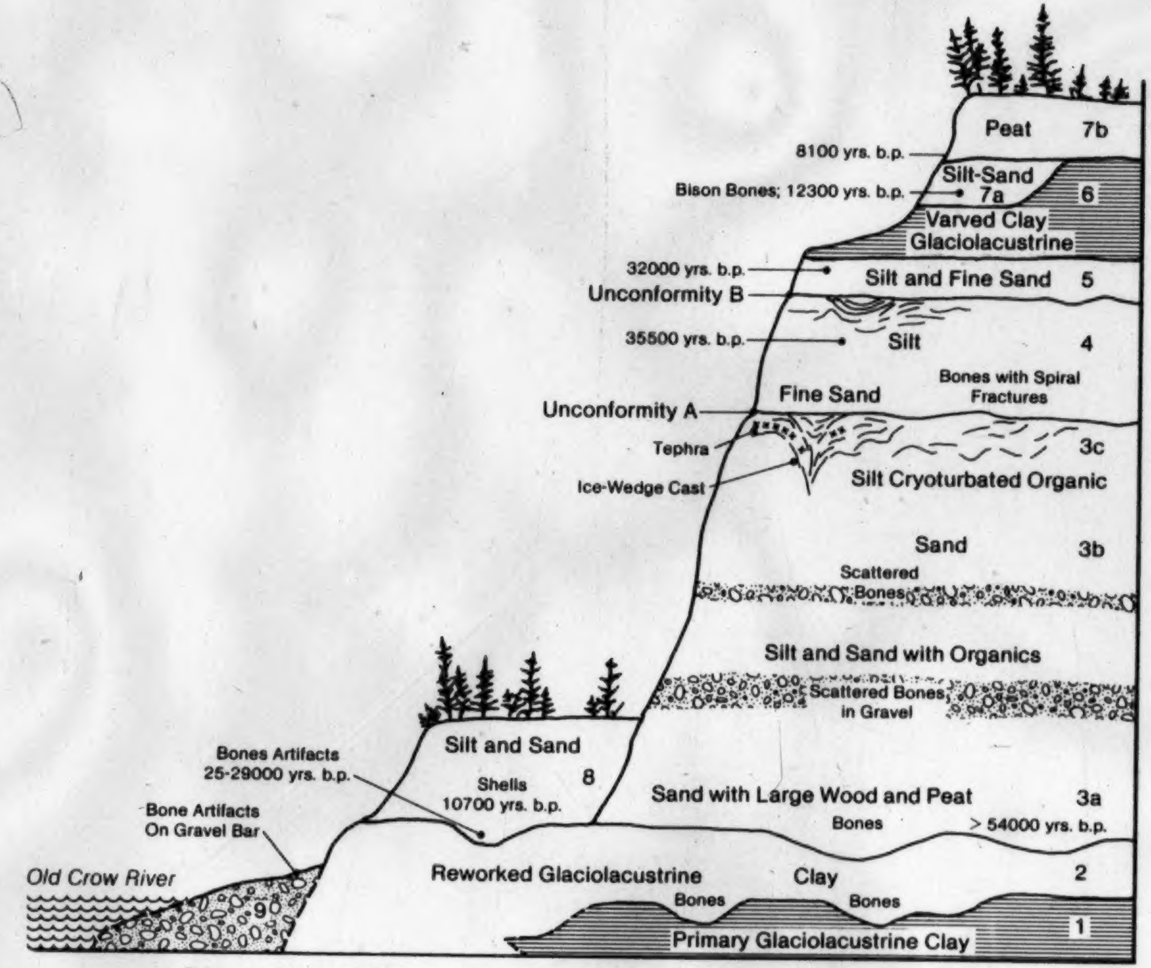
Peat
7b
8100 yrs. b.p.
Silt-Sand
7a
6
Bison Bones; 12300 yrs. b.p.
Varved Clay
Glaciolacustrine
32000 yrs. b.p.
Silt and Fine Sand
5
Unconformity B
35500 yrs. b.p.
Silt
4
Bones with Spiral Fractures
Fine Sand
Unconformity A
Tephra
3c
Ice-Wedge Cast
Silt Cryoturbated Organic
Sand
3b
Scattered Bones
Silt and Sand with Organics
Scattered Bones in Gravel
Silt and Sand
Shells
10700 yrs. b.p.
8
Bones Artifacts
25-29000 yrs. b.p.
Bone Artifacts
On Gravel Bar
Sand with Large Wood and Peat
3a
Bones
> 54000 yrs. b.p.
Old Crow River
9
Reworked Glaciolacustrine
Clay
2
Bones
Bones
Primary Glaciolacustrine Clay
1

Figure 4: Old Crow Basin Composite Section
(taken from Morlan, 1978)

TABLE 3: Stratigraphic Section, south bank of Porcupine river (taken from Hughes 1969, youngest unit on top)

UNIT	DESCRIPTION	THICKNESS(meters)
9	Silt, probably eolian	0.76
8	Peat, wood, mostly humified	0.91
7	Silt, grey-brown, with twig and wood lenses thin peaty layers; probably fluvial	8.38
6	Clay, silty, dark grey(moist), pale grey(dry); sediments slumping and flowing and poorly exposed; glaciolacustrine	3.20
5	Silt and very fine-grain sand, dark grey to dark-brown (moist), yellow-brown (dry); gravel lens 1 foot thick in middle of unit; lacustrine and fluvial	11.27
4	Silty grey-brown(moist), yellow-brown (dry), lenses of gravel and of twigs and wood; bedding in upper 3 to 4 feet highly convoluted by cryoturbation	6.25
3	Silt, dark grey-brown(moist), medium brown-grey(dry); massive; markedly jointed with oxidized joint surfaces; glaciolacustrine; overlies unit 2 disconformably.	12.64
2	Silt sand fine bedded, grey-brown to yellow-brown; twig and wood layers abundant in lower 25 feet; upper 4 feet highly convoluted by cryturbation, with convolutions truncated at contact with unit 3; overlies unit 2, disconformably.	12.19
1	Sand coarse, and fine gravel, with a few thin silt layers grey in oxidized to dull red brown; very compact cf units 2, 4, and 5; abundant logs(spruce) with diameter to 20 inches.	3.65
	TOTAL	59.28

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west. The glaciolacustrine sediments (Unit 6 from both Table 3 and Fig. 4) that were laid down at this time are known to have been deposited sometime after 32,000 B.P. (Morlan and Matthews, 1978). Therefore the second ice advance can be correlated to the Late Wisconsin Stadial. This also means that an Early Wisconsin ice advance does not show up in the geological record of this region.

Following the retreat of the last ice advance the western drainage flow became permanently established. There were two reasons the easterly direction of the previous drainage was not re-established. Firstly, the Ramparts channel was now downcut below any passageways to the east. Secondly, many of the passes including the McDougall Pass had become partially filled with glacial fluvial and glaciolacustrine material, thereby creating permanent dams.

Post lake alluvium and peat deposits document the history of the basins after the lakes drained, (Units 7 and 8 from Table 2; Units 7a and 7b from Fig. 3). The peats are considered to be of Holocene age (radiocarbon date of 8,100 B.P. at the base). The basins have since been cut by the various rivers within each basin, and this has exposed large alluvial sections (see Plates 1 and 2).

Chapter III. Methods of Study

Bluefish River Study Site

(a) Location and Description

The Bluefish River study site (HH - 75 - 24; see Fig. 2) is approximately 30 kilometres southwest of the native settlement of Old Crow, and is located along the Bluefish River (67° 23′ N latitude, 140° 21.5′ W longitude), at an elevation of about 300 metres. The study site, which is situated on the western edge of the Bluefish Basin, is an alluvial section that has been exposed by the downcutting of the Bluefish River.

The exposure, which is about 40 meter high, is the southfacing cutbank of a fairly tight meander. The top of the exposure, which is not well drained, is dominated by stunted black spruce (*Picea mariana*). The sides of the cutbank and other better drained areas are inhabited by white spruce (*Picea glauca*). The shrub layer is comprised of shrub birch (*Betula glandulosa*), soapberry (*Shepherdia canadensis*) and willows (*Salix* spp). The herb component and the moss cover are similar to the species previously mentioned in the description of the vegetation of the region (see also Appendix A).

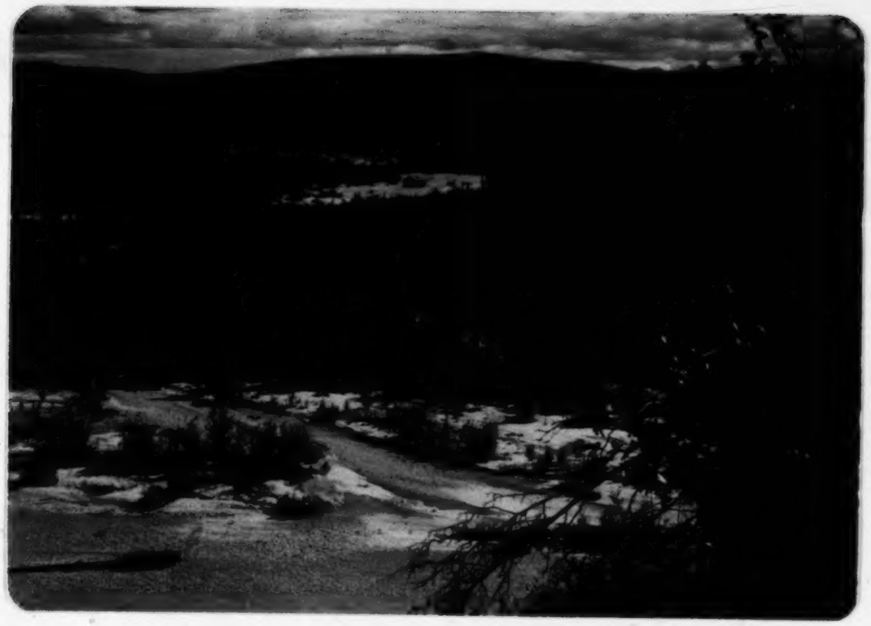
The point bar and alluvial flats show the vegetational zonation that has already been described, with willows

Plate 2

(a) Photograph taken from the top of the Bluefish River exposure, showing the vegetation (especially the presence of spruce) around the study site.

(b) Photograph showing the vegetational zonation along the alluvial plain, with willows closest to the river, followed by poplar and finally spruce.

PLATE 2



COLOURED PICTURES
Images en couleur

(*Salix* spp.) closest to the river, followed by poplar and finally by stands of spruce (usually *Picea glauca*; see Plate 2b).

(b) Stratigraphy and Chronology

The sediment description of the Bluefish River section is described in Table 4. Unit 1 is the partially exposed underlying bedrock (see Plates 3 and 4). The bedrock is probably equivalent to the Devonian Gossage carbonate, a brecciated dolomite with chert clasts known to be exposed to the northeast at the junctions of the Driftwood and Porcupine Rivers (Miall, 1973).

The overlying lignite coal seam (Unit 2) is considered to be Tertiary (Oligocene) or earliest Pleistocene in age (Hopkins, Geological Survey of Canada, written communication). Hopkins bases his age on the pollen analysis of the coal, although he does state that the pollen flora is not very conclusive in terms of trying to assign an age to the unit. The presence of *Juglans*, *Pterocarya*, *Corylus* and *Tsuga* does tend to suggest that this unit is probably Tertiary in age, as they are all members of the Tertiary flora of Alaska (Wolfe, 1972).

Units 3 to 8 inclusive can be grouped together into one larger unit, which from now on will be referred to as the lower Bluefish unit. The lower Bluefish unit sediments represent valley fill alluvium and these sediments are here

TABLE 4: Stratigraphy for Bluefish river Section(HH-75-24, youngest unit at top)

UNIT	DESCRIPTION	THICKNESS(m)
12	Organic mat(samples 61,62 for pollen)	0.30
11	Silt, mottled grey, sand stringers, organic layers along bedded plains; Sand stringers, ripple bedded and current bedded; Ice lenses throughout, badly cryoturbated in places (samples 15-60 for pollen)	4.50
10	Sand, yellow grey; dark grey silt stringers; fine woody stringers; ripple marks present (samples 1-14 for pollen)	1.40
9	Sand and gravels, very coarse grained sand; channel fill deposits; probably fluvial; spruce logs exposed, abundant wood fragments (collected for amino acid analysis)	5.95
8b	Silt,brown; more clay less sand (two pieces of wood for amino acids, samples 101-108 for pollen)	1.40
8a	Silt,brown; very fine grained sand present in large amounts; very friable; ripple bedded; twigs and large size wood fragments (two pieces of wood for amino acids, samples 87-100 for pollen)	2.85
7b	Sand, yellow grey; coarse grained, some pebbles, loosely consolidated, poorly sorted; possibly channel lenses	0.32
7a	Sand, grey-yellow; very fine grained, consolidated; silt stringers present	0.17
6b	Silt, mottled dark grey to dark red brown at base; reddish brown sand lenses; upper 0.3 meters greenish grey, massive (samples 78-86 for pollen)	1.80
6a	Silt at base, grades upward to fine grained sand, dark brown; organic wood layers common (two organic trash units sampled, wood for amino acids, samples 74-77 for pollen)	0.70
5b	Sand, grey-yellow, fine grained; brown silt stringer	0.15

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TABLE 4(con't)

UNIT	DESCRIPTION	THICKNESS(m)
5a	Sand, grey-yellow, medium to coarse grained; some pebble size gravel present; upper 20 cm reddish yellow; few blue grey silt stringers	1.60
4c	Silt, blue grey;large amounts of sand; organic detritus; upper contact mixed slightly with overlying sand (samples 71,72,73 for pollen)	0.55
4b	Silt, blue grey; very little sand; organic detritus (samples 67-80 for pollen)	0.43
4a	Silt, blue grey; large amounts of reddish yellow sand; limonitic concretions (samples 63-66 for pollen)	0.44
3	Gravel, dark grey to yellow red; pebble and cobble size; some silt stringers; gravel lenses sits uncomformably on the underlying Tertiary coal seam, set into slight depression, gravels may be Tertiary or Pleistocene; upper contact is contorted and there is some mixing with underlying unit	0.40
2	Coal, black, lignitized wood; silt and sand; grades upward to become a silt, dark grey to dark brown, clayey; scattered organic fragments and coarse grained sand.	2.10
1	Dolomite, weathered, brecciated, friable, weathers yellow, fresh colour while grey; clasts in grey silt matrix; upper 0.5 meters deeply weathered, but not as friable, yellowish red in colour, maybe Tertiary soil	2.68
	Covered interval; where exposed friable weathered dolomite, white to yellow red in colour	8.52
	TOTAL	36.35

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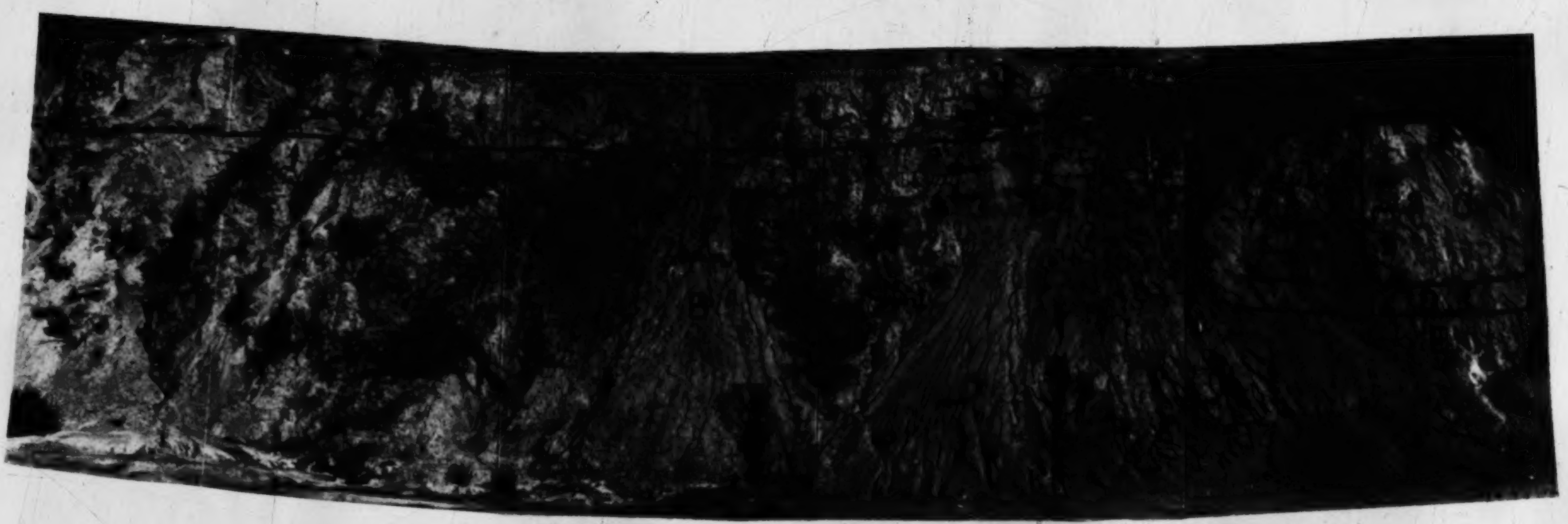
Plate 3

Bluefish River study site section showing the upper Bluefish unit (A), the middle unit (B), the lower Bluefish unit (C) and the underlying coal seam (D) and bedrock (E). Note the downcutting of the middle Bluefish unit through units (C) (D) and (E). Stations 1 and 2 are the parts of the section that were sampled for pollen.

PLATE 3



believed to be Pleistocene in age.

There exists a major unconformity between unit 8 of the lower Bluefish unit and the overlying unit 9 (middle Bluefish unit). A major channel was cut through the lower Bluefish unit as well as units 1 and 2 (see plate 3). This channel was filled with fluvial sands and gravels which represent unit 9.

The remaining three units (10, 11, 12) can be grouped into the upper Bluefish unit. Units 10 and 11 were probably deposited in a shallow water near shore deltaic environment. The upper Bluefish unit is more than likely Late Wisconsin in age since it represents the last lake in the Bluefish Basin (see Morlan and Matthews, 1980). The underlying unit 9 may represent Early and Middle Wisconsin times. Unit 12 is considered to be part of the extensive peat development that took place in the region during the Holocene (Morlan, 1978).

The correlation of the Pleistocene sediments from the study site with the general Pleistocene stratigraphy outlined in the previous chapter is very tentative. Firstly, there are no absolute dates for this section. A single radiocarbon date on a spruce log taken from the Middle Bluefish unit (Unit 9) was greater than 54,000 B.P.. Secondly, even a stratigraphic correlation is difficult because the glaciolacustrine units that are present in both the Porcupine River section (Table 3) and the Old Crow Basin composite section (Fig. 3) are missing from the Bluefish

River exposure. To understand the reason for their absence and how the lithofacies of the study can be correlated with the general Pleistocene stratigraphy put forward by Hughes (1968) and Morlan and Matthews (1978) it is neccessary to discuss the facies relationships in terms of paleogeography.

For the most part the study site would have been an area where large volumes of sediment accumulated as some form of valley fill alluvium. However, it should be noted, that the study site is located very near the western edge of Bluefish Basin and not in the interior parts of the basin as is the case with the sections studied by Hughes (1968), Lichti-Federovich (1974) and Matthews (1975) (see Fig. 2; sites 7,8). This would mean that during the major Laurentide glacial advances, in which the regional drainage systems were blocked and the Bluefish Basin became filled with water, the area of the study site would have been part of, or very close to the lake shoreline. Therefore the sediments deposited at the study site during the lake highstands, would be representative of shallow water deltaic or near shore lacustrine environments and not the deep water lacustrine sediments that you would expect, and do find, in the interior parts of the basin (see above references).

The following suggested chronology of the Bluefish River section and its possible correlation with the Pleistocene stratigraphy of the Bluefish Basin is to be considered tentative. The coarse sands and gravels (see

Table 4, unit 3) which occur at the base of the lower Bluefish unit are correlated to the sands and gravels (see Table 3, units 1 and 2) that are part of the earliest recognized sediments deposited in the Bluefish Basin. These are thought to have been deposited prior (possibly pre-Illinoian) to the onset of the first recognized Laurentide ice advance. During this time, the entire Bluefish Basin as well as the area of the study site were being filled with fluvial and deltaic deposits. The sands and silts that make up the rest of the lower Bluefish unit (units 4 to 8 inclusive, Table 4) were deposited as organic valley fill alluvium. Unfortunately because there is such poor dating control the age of these sands could range anywhere from pre-Illinoian to Sangamon. Therefore, any attempt to correlate these sediments to other deposits within the Bluefish Basin would be, at the present, very hazardous.

The Middle Fluvial unit (unit 9, Table 4) which is deposited in a channel cut down through the lower Bluefish unit and the underlying bedrock (see Plate 3) is thought to represent sediments deposited prior to the Late Wisconsin Laurentide ice advance, and was probably part of the meandering river system that was present in the region at this time (Morlan, 1978). The fluvial sediments can be correlated to other fluvial and deltaic sediments (units 4 and 5, Table 3) which exist at similar stratigraphic levels in other parts of the Bluefish Basin. The presence of spruce logs within the Middle Fluvial unit, plus the previously mentioned > 54,000 B.P. radiocarbon date, suggest that this unit is older than most of the Middle Wisconsin and might possibly be Early Wisconsin or even Sangamon in age. A Sangamon age is supported by a number of workers (Hopkins, 1964; Colinvaux, 1967) who believe that during the Sangamon the climate was warm enough for the tree line to re-advance to the north.

The Late Wisconsin Laurentide glaciation (Late Wisconsin) once again dammed the drainage to the east causing the Bluefish Basin to refill with water. Consequently, while glaciolacustrine sediments (Units 6 and 7, Table 3; Units 6 and 7a, Fig. 3) were being deposited in the deeper central parts of the basin, shallow water near shore lacustrine and deltaic sediments that comprise the upper Bluefish unit (Units 10 and 11, Table 4) were being deposited in the vicinity of the study site. The peat layer that overlies the upper Bluefish unit can be correlated to the extensive peat layers (Unit 7b, Fig. 3; Unit 8, Table 3) that developed throughout the Bluefish and Old Crow Basins during the Holocene.

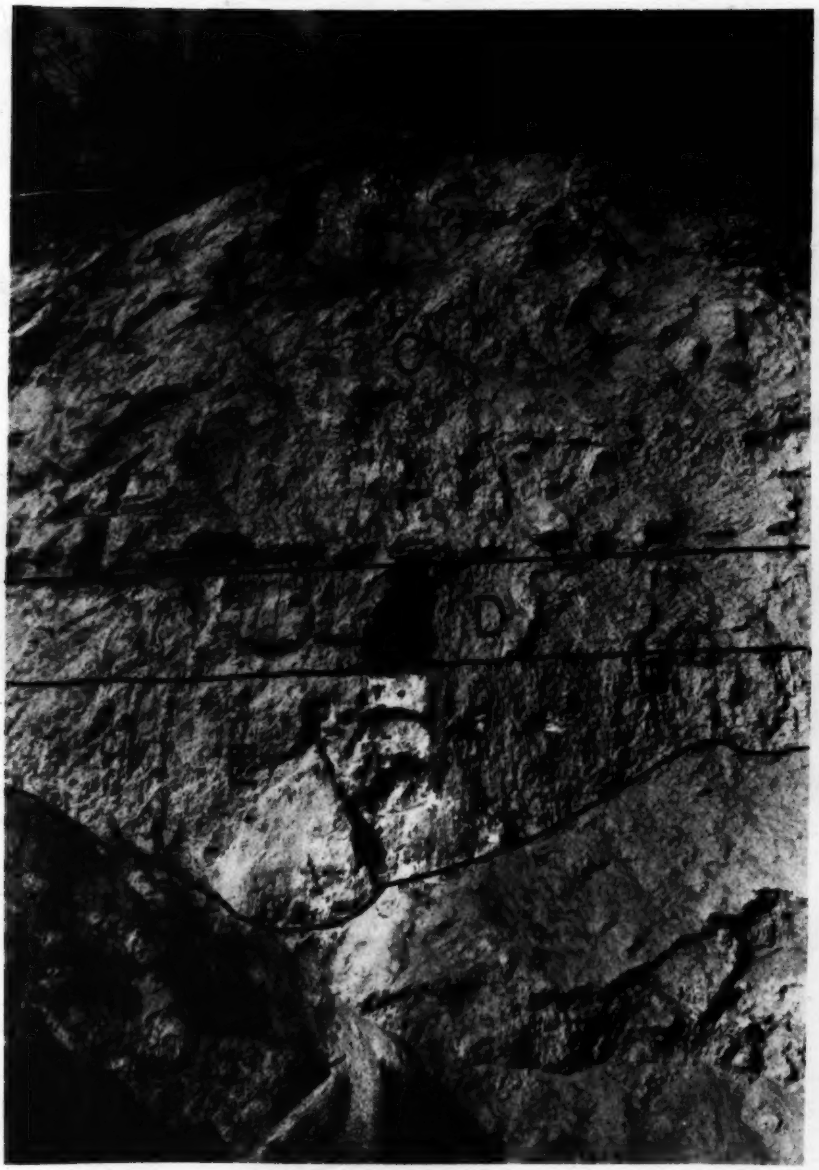
Field Methods

The field work for this study was carried out during the summer of 1977. The samples of sediment collected for pollen analysis were taken fom the section using a series of

Plate 4

Photograph showing a closeup view of the relationship between the lower Bluefish unit (C), and the underlying coal seam (D) and bedrock (E). Note the trenching method used for sampling pollen.

PLATE 4



trenches dug up the side of the exposure (Plate 4). Each trench was dug inwards one to two meters from the surface and was approximately two meters high. The reasons for removing this amount of material were (1) to make sure a fresh face was exposed, so that the effect of weathering would be minimal and (2) to remove the possibility that we were sampling material that had slumped down from above.

Units (5) and (7) which are part of the lower Bluefish unit, were not sampled because it was felt that these units were too coarse grained and would not contain any pollen (see discussion in Faegri and Iverson, 1964:51-78; also Tschudy, 1969, Ch. 5). The middle fluvial gravel unit (unit 9) was also not sampled for similar reasons.

A great deal of care was taken to avoid contaminating the samples. Each sample was taken from a fresh surface, using clean trowels and spatulas, and placed in a 25 ml. plastic bag which was sealed immediately. The samples from the lower Bluefish unit were collected using a 20 cm sampling interval. A 10 cm sampling interval was used in the upper Bluefish unit. Altogether one hundred and eight samples were collected; forty-six from the lower unit and sixty-two from the upper unit.

Three bulk samples of the organic trash layers were also collected. One sample was taken from the only trash layer of the upper Bluefish unit, while the other two samples were obtained from the lower Bluefish unit. The samples were analysed for fossil bryophytes by J. Janssens. The results of his work will be presented later in this report. Wood samples were gathered from many parts of the middle Bluefish unit and the lower Bluefish unit. These samples are being analysed for amino acids at the University of Alberta. The final results of the analyses are not available (Rutter, personal communication).

Surface samples were taken along the top of the exposure. A "pinch" sample was taken from moss polsters and organic debris every five meters in all directions from a central point. Altogether, about 30 "pinch" samples were collected and analysed in order to compare the modern pollen rain with the present vegetation cover.

Laboratory Methods

(a) Pollen Analytical Methods

Pollen in the surface samples and in the sediment samples were concentrated in the laboratory using a method that was developed at the Paleoenvironmental Studies Laboratory at the University of Alberta (see Appendix B). Pollen from all samples were stained with Safranin and mounted with glycerin for counting.

All samples were counted with a LEITZ SM-Lux binocular microscope. Pollen grains were counted with 10x Periplan occulars and a 40x NPL fluorite objective (numerical aperture 0.70). Critical identifications and examination of unknowns and poorly preserved grains were identified using a 100x NPL oil immersion lens (numerical aperture 1.30). A minimum of 200 pollen grains were counted for each slide. Traverses were spaced regularly 500 um apart, and at least half a slide was counted. This was done to try and avoid a possible bias brought about by differences in pollen grain size (Maher, 1977) and hopefully to avoid the non-random distribution of pollen on a glass slide (Bookes and Thomas, 1967). The pollen sum (ΣP) includes all pollen of extant vascular plants, as well as aquatic taxa. The pollen sum does not include: mosses, algae, pre-Quaternary spores and indeterminable grains.

All pollen identifications were made with the aid of the reference slide collection of the Paleoenvironmental Studies Laboratory at the University of Alberta and also with the aid of available keys (Faegri and Iverson, 1964; McAndrews *et al*., 1973; Habgood, unpublished data). Spores and mosses were determined using McAndrews *et al* (1973). Pre-Quaternary spores were identified using descriptions and illustrations in Tschudy and Scott (1969).

Indeterminable pollen which were not too badly preserved were classified into three groups according to their type and number of apertures. This classification is based on a method that was suggested by Rampton (1971a:969). Indeterminable spores were classified into two groups, (a)trilete spores and (b) others.

All pollen and spore determinations were made to the lowest possible taxonomic level.

The surface smaples were collected by gathering moss pollsters and detritus from the floor of the open spruce forest that lies above the alluvial exposure. The samples were processed as one sample bacause they were all collected within a twenty-five meter radius. A total of a thousand pollen grains were counted and the results are shown in Table 5.

(b) Grain Size Analysis

The pollen results from the upper BLuefish unit show four sterile zones. Grain size analysis was performed on 15 samples spanning the entire unit to determine if there was a relationship between granulometric composition and absence of pollen.

The grain size distributions were determined using the preparation, sieving and hydrometer techniques described in the Glacial Geology Field and Laboratory Manual developed by the Quaternary Reasearch Group at the University of Alberta (unpublished data). This manual follows the methods outlined in the Procedures for Testing Soils, the American Society for Testing Materials (1964). The grain size analysis results are shown in Fig. 11 and Appendix C.

Chapter IV. Pollen Results

Treatment of Pollen Results

The results of the pollen analysis from the sediments are presented in two relative frequency pollen diagrams - one for the lower Bluefish unit (Fig. 5), the other for the upper Bluefish unit (Fig. 6). The relative frequencies are expressed as a percentage of the sum (ΣP). This sum includes aquatic taxa. Taxa that were not included in the pollen sum are treated separately. This follows the suggestions of Faegri and Iverson (1964). These taxa are expressed separately as a percentage of the sum of pollen plus the sum of each included taxa. For example, the indeterminable grains are expressed as a percentage of the sum of pollen (Σ P) plus the sum of indeterminable grains (Σindet.). Any taxa which make up less than 2% of the total are shown as black dots.

Surface Sample Results

The dominant pollen type is *Picea* (40%) followed by *Alnus* (15%), *Betula* (12%) and Cyperaceae (12%) (Table 5). Two fairly important components of the vegetation are under-represented by the pollen rain; these are *Salix* (2%) and *Populus* (4%). This is probably due in part to poor preservation of the pollen grains, especially *Populus*, which is known to degrade fairly rapidly (Havinga, 1971). However, the major reason for this under-representation is probably

TABLE 5: Surface Sample Results

(a) Pollen(1027 grains counted)

Type	Percentage(≥0.5)
Picea	41.9
Pinus	0.6
Populus	3.8
Betula	11.8
Alnus	14.6
Salix	3.5
Ericaceae	1.2
Cyperaceae	11.2
Gramineae	4.8
Artemisia	1.6
Cruciferea - *Draba* type	0.9
Umbelliferae	0.9
Liliaceae - *Toefieldia* type	0.8

(b) Pollen Types(Percentage≤0.5%)

Compositae - *Taraxacum* type, Tubuliflorae, *Shepherdia canadensis*, Ranunculaceae - *Anemone* type, *Thalictrum*, *Rosa acicularis*, *Rubus chamaemorus*, *Polygonum amphibium* type, Caryophyllaceae, *Saxifraga hirculus* type, *S. nivalis* type, Cruciferae - *Cardamine* type, Gentianaceae, Labiatae - *Galeopsis* type, Rubiaceae - *Gallium* type

(c) Spores and Algae(336 grains counted)

Type	Number Counted
Sphagnum type	38
Botrychium	1
Lycopodium anotinum type	2
Lycopodium selago type	1
Equisetaceae	18
Pediastrum	3
Indeterminate Bryophytes	273

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related to the fact that the poplars and willows are more commonly located along the river flats, whereas the surface sample was taken in the spruce forest where the spruce pollen undoubtedly dominates the pollen rain.

The small amount of pine pollen that is present is the result of long distance transportation since the closest pine trees are located about 240 kilometers to the south. All other pollen types identified within the sample can be attributed to the vegetation present on or very near the study site.

Ager (1975), Matthews (1970) and Rampton (1971a) have all described similar surface pollen spectra from spruce forested regions in interior Alaska and southern Yukon. Lichti-Federovich and Ritchie (1968) have documented surface pollen spectra from spruce forest-tundra regions in parts of the western interior of Canada that are very similar to the surface pollen results from the Bluefish study site. This does not mean, however that a similar pollen spectra from a fossil locality is indicative of a spruce forest or spruce forest-tundra type vegetation. Ritchie and Lichti-Federovich (1967) have shown spruce forest-tundra environments in the arctic-subarctic Canada that produce pollen results quite unlike the previously mentioned surface sample analyses. Birks (1977) has documented surface sample results from the St. Elias Range, southwest Yukon, that show similar pollen spectra for both *Picea glauca* forests and shrub tundra type vegetation. Even with the aid of statistical methods Birks was unable to distinguish between the pollen for the shrub-tundra and the *Picea glauca* forest.

Therefore, although the surface sample results do correlate fairly well with the present vegetation at the study site, other evidence suggests that much more work is required to be able to understand the relationship between pollen rain and the distribution of the vegetation.

Relative Pollen Diagrams

Separate pollen diagrams (Figs. 5 and 6) were drawn for the lower Bluefish unit and the upper Bluefish unit although they were from the same section. This was done because the two units were separated by the large unsampled middle Bluefish unit. This would have made it very awkward plotting the pollen results and still illustrate the large gap that exists between the two diagrams. However, the boundaries or zones established within the pollen data were designated as if there was only one diagram. There were eight zones established for the whole section; zones BF 1 through BF 4 for the upper Bluefish pollen diagram (Fig. 6) and zones BF 5 through BF 8 for the lower Bluefish pollen diagram (Fig. 5).

Pollen zones were established for intervals exhibiting distinct fossil assemblages or as in the case of Zone BF2, a sterile zone. Zone BF2 is discussed in greater detail further on in this thesis. The Zone BF7/Zone BF6 and Zone BF 6a/Zone BF 6b boundaries were split by a coarse sand interval and the boundaries for these zones were placed: 1) where the last sample was collected just before the base of a sand unit and 2) where the first sample was taken immediately above the upper boundary of a sand unit.

(a) Lower Bluefish Pollen Diagram (Fig. 5)

Zone BF 8 (samples 63 - 69)

This lowermost zone is dominated by Cyperaceae pollen with values consistently between 25 and 35%. *Betula* is also prominent with values ranging from 15 to 35%. *Picea* (10 - 20%) and *Pinus* (2 - 7%) are consistently present, as are *Salix* and *Alnus* each of which make up 5 to 7% of the pollen rain. Shrub taxa are represented by Ericaceae, which reaches values of 15% and *Corylus* which attains its maximum level (3 - 5%) in this part of the diagram. With the exception of Cyperaceae the herb component is very sparse. Gramineae never exceeds 7%, while *Artemisia* and *Potentilla* - type, the only other herbs that appear thoughout this zone never attain values of more than 2%. *Sphagnum* is the dominant moss. The total indeterminate pollen is fairly abundant reaching values of 30%, with the majority of the grains being indeterminate conifers and triporate indeterminate. The upper boundary of this zone is marked by a rapid increase in *Betula* and an equally rapid decrease in Cyperaceae pollen.

Zone BF 7 (samples 70 - 73)

Betula increases from 35% to 55% very rapidly in this zone, while Cyperaceae and *Picea* drop to approximately 10% and 20% respectively. *Pinus*, Ericaceae and *Corylus* all stay around the values found in zone BF 8. *Alnus, Salix* and Gramineae all decrease to fairly insignificant amount (less than 2%), while *Artemisia* (2 - 5%) appears consistently for the first time. Other herbs are again very uncommon with *Potentilla* - type and Caryophyllaceae the only types consistently occurring in this level. The indeterminate pollen never reaches 15% with conifer indeterminates becoming almost negligible, which is consistent considering there is a decrease in identifiable conifer pollen. The dominant moss is still *Sphagnum* - type although it is not as abundant (2 - 10%) as in the previous zone. *Botrychium* appears in two samples (70,71) at relatively high levels (4 - 6%) while *Selaginella selaginoides* type never rises above 2%: The upper level of this zone is delineated by the base of the first sand unit that was not sampled for pollen.

Zone BF 6 (samples 74 - 103)

This zone occupies the major part of the lower Bluefish unit and it is characterized by a dominance of Cyperaceae pollen (25 - 50%). Gramineae (2 - 10%) and *Artemisia* (1 - 8%) are other herbs that appear consistently throughout this zone. *Potentilla* - type, Rosaceae undiff., Caryophyllaceae and *Arabis* - type all occur regularly at values of less than

2%. *Betula* is still present in this zone, although it is far less common (20%) than in zone BF 7 and shows a consistent decrease in relative percent from the base of the zone (20%) to the upper boundary (less than 10%). *Picea* and *Pinus* also exhibit the same trend as *Betula*, being more common at the base of the zone (5 - 10% and 3 - 5% respectively) and decreasing in values as you progress upwards (generally less than 2%). *Alnus, Salix* and Ericaceae remain relatively constant throughout the zone, although *Alnus* does tend to show a relative increase (up to 20%) in the upper part of the zone. *Corylus* disappears altogether, while *Larix* makes its first appearance; initially only in traces (less than 1%) but in the upper half of the zone it attains values ranging between 2 and 4%. There is a marked increase in the diversity of mosses and ferns in this zone. *Sphagnum* - type mosses are by far the most dominant ranging in value from 2 to 25%. Polypodiaceae, *Botrychium* - type, *Selaginella selaginoides* type and *Lycopodium annotinum* - type all appear regularly in this zone attaining values up to 4%, but for the most part never reaching more than 2% of the total pollen and spore rain. The individual indeterminate categories almost never exceed 10% and each category accounts for about 5% of the total sum. The upper contact of the zone is formed by a marked increase in *Betula, Alnus, Sphagnum, Pediastrum* and Gramineae, as well as a significant decrease in Cyperaceae, and the disappearance of *Artemisia*. Zone BF 6 has been divided into two subzones.

(i) Subzone BF 6b (samples 74 - 86)

This subzone is characterized by a relatively higher non-herbaceous component. *Picea, Pinus* and *Betula* are all more abundant in this subzone, while *Artemisia* rarely exceeds 1%. With the exception of Cyperaceae, the herb component is relatively small and represented by very few pollen types. *Larix* is present in this subzone but like *Artemisia* rarely exceeds 1%.

(ii) Subzone BF 6a (samples 87 - 103)

The increase in the diversity of the herb component is the most significant trait of this subzone. *Artemisia* increases (2 - 10%) along with *Potentilla* - type, Caryophyllaceae and *Arabis* - type. This subzone is also the only place where *Shepherdia canadensis* appears consistently. *Picea* and *Pinus* never exceed 2%, while *Larix* shows an increase attaining values of up to 4%. *Betula* also displays a relative decrease rarely exceeding 15%, while *Alnus* increases reaching in some cases values of 20%. This subzone is also the only level where Equisetaceae consistenly appears, although never at values greater than 2%.

Zone BF 5 (samples 104 - 108)

Significant increases in *Betula* and *Alnus* and to a lesser extent Gramineae, along with coincidental decreases in Cyperaceae and *Artemisia* pollen are the traits that characterize this zone. *Betula* increases from 17% to 34%, while *Alnus* reaches its maximum value (30%) for this pollen diagram. *Picea, Pinus* and *Shepherdia canadensis* have for the most part disappeared. It should be noted that *Pterocarya* is also present in this zone but only as a minor constituent. The herb component, with the exception of Gramineae, decreases dramatically with Cyperaceae declining steadily to 7%, while *Artemisia* and the other herbs are reduced to trace levels (less than 2%). There is a substantial increase in *Sphagnum* - type spores from 20 to 40% along with a major increase in *Pediastrum* (17 to 30%). *Isoetes* makes its first and only appearance in this zone. The indeterminate category also demonstrates a slight increase, with the majority of the grains belonging to the miscellaneous indeterminable group.

(b) Upper Bluefish Pollen Diagram (Fig. 6)

The zones established for this part of the section were considerably more difficult to determine because of the numerous sterile zones in the upper part of the diagram.

Zone BF 4 (samples 1 - 37)

This zone is totally dominated by the herbaceous component especially Gramineae (10 - 50%), Cyperaceae (5 - 35%) and *Artemisia* (10 - 40%). Chenopodiaceae - *Amaranthus*, Tubuliflorae, Liguliflorae, Caryophyllaceae, and Cruciferae - *Arabis* type all contribute to the diversity of the herbaceous taxa, although they rarely exceed 2%. The non-herbaceous component is practically non-existent, with *Picea*, *Betula*, *Alnus*, *Salix* and Ericaceae never reaching values greater than 5% except in the upper part of the zone where *Betula* and Ericaceae increase to 12% and 20% respectively. The identifiable spore component is almost negligible with *Sphagnum* being the only type that is consistently present, although it rarely exceeds 5%. Indeterminable spores are present throughout especially in the upper part of the zone where they reach values of 20%. The indeterminable pollen grains generally fall into two categories; the indeterminable miscellaneous group or the tricolpate (tricolporate) indeterminate group. They are less common (5%) at the base of the zone and increase toward the upper boundary, with each type accounting for 15 to 20% of the total sum. Pre-Quaternary spores, which were not present in the lower Bluefish unit, are also present in this zone and like the indeterminable pollen shows an increase from the base of the zone (2%) to the upper boundary (30%). The upper boundary of this zone is delineated by a marked increase in Gramineae pollen concomitant with a decrease in *Artemisia* and Cyperaceae. Zone BF 4 has been subdivided into three subzones.

(i) Subzone BF 4c (samples 1 - 11)

This subzone is characterized by high amounts of Cyperaceae (20 - 35%), *Artemisia* (25%) and Gramineae (25 - 50%) pollen. There is relatively rich herb component that appears at values of less than 2%. These include Chenopodiaceae - *Amaranthus*, Tubuliflorae, Liguliflorae, Caryophyllaceae, *Saxifraga hirculus* - type and Cruciferae - *Arabis* type. *Betula*, *Salix* and *Alnus* are all present but rarely above 5%. Pre-Quaternary spores are completely absent, while Quaternary spores never exceed 3%. The total indeterminable pollen grains account for 20% with the miscellaneous group (5 - 15%) being slightly more abundant than the indeterminate tricolpate (tricolporate) group (4 - 10%).

(ii) Subzone BF 4b (samples 13 - 19)

This subzone is marked by a dramatic increase in *Artemisia* (40 - 50%) and a coinciding decrease in Cyperaceae (5 - 10%) while Gramineae pollen shows little change. The minor herb component is not as diversified with only *Arabis* - type and Liguliflorae consistently present from the previous subzone. This subzone also documents the first and only appearance of *Phlox*. The arboreal component is for the most part scarce with *Picea*, *Betula*, *Alnus* and *Salix* appearing only sporadically throughout this level and never at values above 4%. Pre-Quaternary spores remain at the same level as the previous subzone (4c). The indeterminable pollen sum decreases very slightly, never rising above 15%, with the same two groups of indeterminates accounting for the majority of the indeterminable grains.

(iii) Subzone BF 4a (samples 21 - 37)

This is the first level where sterile zones were encountered in the pollen record (see Fig. 6). The subzone is still dominated by the major herbs with Cyperaceae showing an increase (10 - 30%) while Gramineae pollen decreases slightly (10 - 25%). The frequency of *Artemisia* pollen is somewhat eratic (13 - 35%) although it is generally lower than the previous subzone. The minor herb taxa has, however, become considerably less diversified and no one type appears consistently within this level. The arboreal component is again very sparse, although one sample (29) demonstrates considerably higher frequencies of *Betula* (12%) and Ericaceae pollen (20%). Pre-Quaternary spores have now become quite significant reaching values between 20 and 35%. There is also an increase in indeterminable spores (up to 20%) along with a rise in indeterminable pollen (20 - 35%) especially miscellaneous (10 - 15%) and tricolporate (tricolpate) (10 - 20%) types. It is possible the tricolpate (tricolporate) indeterminates are very badly preserved *Artemisia* pollen which could mean *Artemisia* is underrepresented in the zone.

Zone BF 3 (samples 39 - 45)

Gramineae pollen dominates this zone accounting for 50 - 80% of the pollen sum. *Artemisia* is still present (15%) while Cyperaceae never rises above 6%. *Picea* and *Betula* are the most common arboreal constituent varying between 1 and

4%. Ericaceae reaches 5% in one sample (41) but like *Alnus* and *Salix* usually does not exceed 2%. The total indeterminable pollen remains relatively unchanged, while the Pre-Quaternary spores are abundant attaining values of up to 85%. The top of this zone is designated by the major sterile zone in the upper part of the section (Fig. 6).

Zone BF 2 (samples 47 - 59)

This zone is completely devoid of extant pollen grains and all that is present are pre-Quaternary spores which account for 100% of the total sum. These spores appear to be Devonian in age and are therefore probably derived from the bedrock (Gossage Formation) of the area. Some of the type include: *Retusotriletes* spp, *Archaeozonotriletes* spp., *Densosporites* spp., *Trileites* spp. and *Calyptosporites* spp. It is unlikely any of the spores are derived from the Tertiary coal seam directly underlying the lower Bluefish unit because there is no evidence of pollen or spore types that might belong to the arcto-Tertiary flora (eg. *Pterocarya, Juglans, Tsuga*).

Zone BF 1 (sample 61)

Assigning a zone based on one sample is not good practice, but this sample is the first sample to contain pollen above the major sterile zone and the pollen spectrum from this sample is very different from all the other zones. The sample is dominated by arboreal pollen with *Picea* (32%), *Betual* (38%) and to a lesser extent *Alnus* (10%) and Ericaceae (10%) being the most common types. The herbaceous component is very small with Gramineae and Cyperaceae accounting for 5 and 2% repectively. There is no evidence of pre-Quaternary spores and the indeterminable pollen accounts for only 10% of the total. Mosses and ferns are fairly inconspicuous with *Sphagnum* type (7%) being the most dominant.

Chapter V. Statistical Analysis and Results

For many years it has been traditional for palynologists to rely heavily upon intuition in an attempt to interpret pollen diagrams. As Adam points out the palynologist can spend a great deal of time "devoted to recognition of patterns present in the data," (Adam, 1974:727). It is for this reason that there has been an increased interest in numerical analysis of pollen data as an aid in subdividing the results into biostratigraphical zones for the purposes of discussion, interpretation and comparison (see Adam, 1974; Birks, 1973a, 1974; Dale and Walker, 1972; Gordon and Birks, 1972; Ritchie and Yarranton, 1978a, 1978b; Yarranton and Ritchie, 1972).

Two statistical analytical methods, cluster analysis and factor analysis, were applied to the pollen data from the Bluefish River section in an attempt to confirm the patterns that had been visually observed within the data. These two methods were chosen primarily because they are the methods that have been demonstrated to be most useful.

Treatment of Data

The lower Bluefish unit and the upper Bluefish unit were treated separately. The lower Bluefish data matrix consisted of 65 pollen types in 46 samples (Appendix D). The upper Bluefish data set contained 31 samples and 45 pollen types (Appendix E). Spores and indeterminable grains were not included in the data. In both matrices pollen percentages and not raw pollen counts were used, because the pollen sums for each sample were different.

Initially a matrix of correlation coefficients between all pollen types was calculated for each set of data (i.e. the upper Bluefish unit and the lower Bluefish unit). There was no attempt made to standardize the data because the correlation coefficients produced for each matrix (see Appendix H and I) did not show an abnormal distribution with unreasonably high coefficients, a phenomena that a number of authors (Orloci, 1967; Underwood, 1969; Adam, 1974) have suggested occurs "because the common pollen types are usually present in rather large numbers, whereas many scarce types are present in frequencies near zero," (Adam, 1974:731). The reason there is no apparent abnormal distribution is probably related to the fact that the majority of the variance within the data cannot be accounted for by an individual variable.

Cluster Analysis

The nature and methods of cluster analysis have been described by Sokal and Sneath (1963) and Rohlf (1970), and therefore will not be outlined in detail in this report. The purpose of cluster analysis is to group together samples in the data set which are alike (highest similarity coefficient).

The method used in this study is group average (average linkage) cluster analysis using the CLUSTAN - 1C computer program developed by D. Wishart (1978). The results of the analysis for both the upper and lower Bluefish units are shown as dendrograms in Figures 7 and 8.

The classification of the samples into the groups or clusters within each dendrogram was done according to the number of pollen zones that the author felt were present in each pollen diagram; for example, the lower Bluefish unit pollen diagram was divided into five zones, consequently the cutoff point for the number of clusters chosen was 5, and these have been designated on Figure 7 by the letters A through E. Similarly, the upper Bluefish dendrogram (Fig. 8) was grouped into 5 clusters (5 pollen zones) again designated by the letters A through E. In an effort to aid in the discussion of the dendrograms, the samples and the groups to which they have been assigned are shown in stratigraphic order in Tables 6 and 7 (this idea is taken from Adam, 1974:734).

(a) Lower Bluefish Unit

For the most part the groups (Fig. 7 and Table 6) derived from the cluster analysis of the lower unit are homogeneous stratigraphically and can be compared favourably with the zonations of the pollen diagram (Fig. 5). The samples represented by Group A can be equated with Zone BF5 (*Alnus-Betula*), while the Group B samples can be correlated

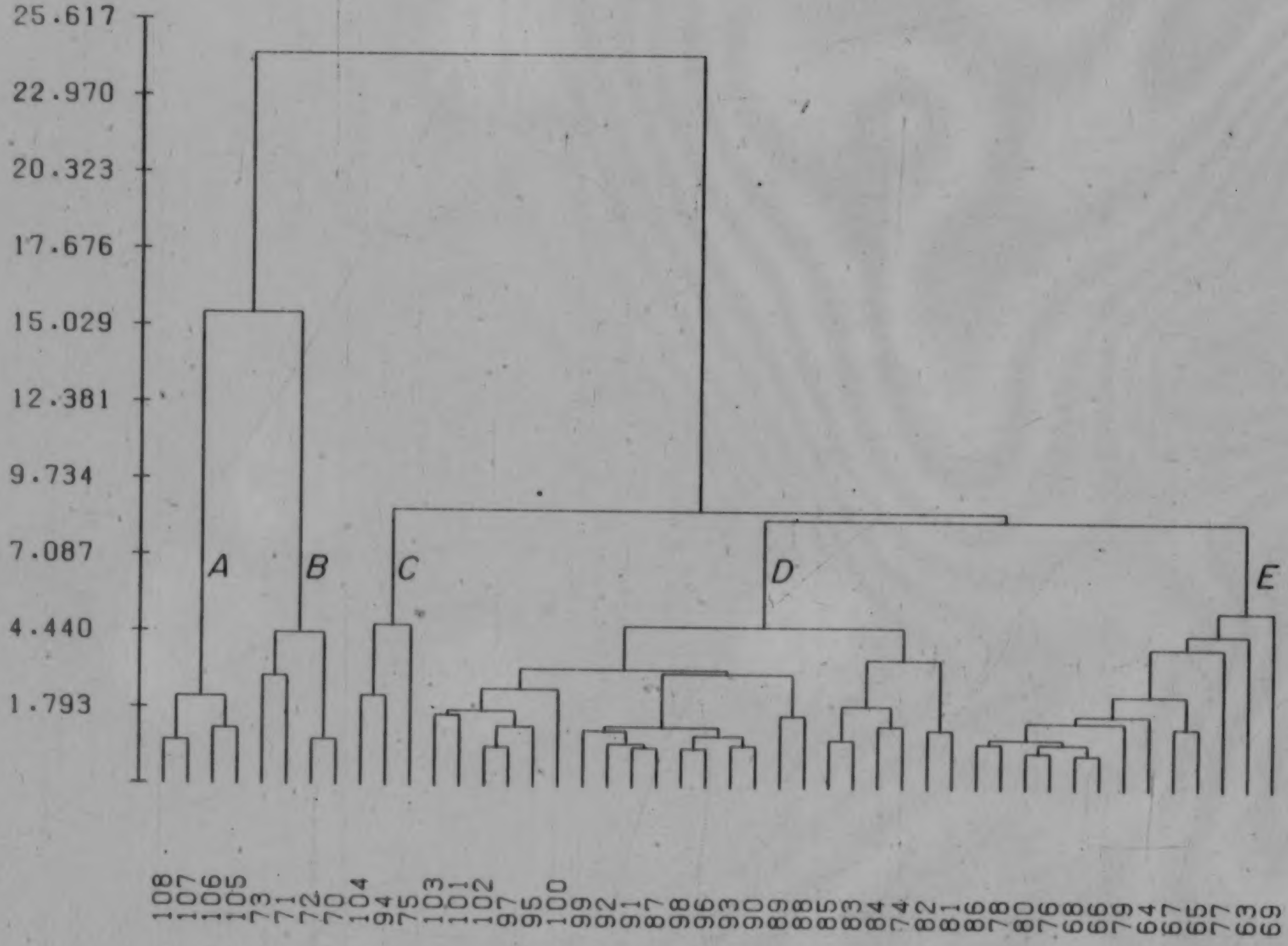

Figure 7: Group Average Cluster Diagram for lower Bluefish unit

TABLE 6: Stratigraphic listing of lower Bluefish unit clusters and equivalent pollen zones

Sample	Clusters					Pollen Zone
	A	B	C	D	E	
108	A					5
107	A					5
106	A					5
105	A					5
104			C			5
103				D		6a
102				D		6a
101				D		6a
100				D		6a
99				D		6a
98				D		6a
97				D		6a
96				D		6a
95				D		6a
94			C			6a
93				D		6a
92				D		6a
91				D		6a
90				D		6a
89				D		6a
88				D		6a
87				D		6a
86				D		6b
85					E	6b
84				D		6b
83				D		6b
82				D		6b
81				D		6b
80					E	6b
79					E	6b
78					E	6b
77					E	6b
76					E	6b
75			C			6b
74				D		6b
73		B				7
72		B				7
71		B				7
70		B				7
69					E	8
68					E	8
67					E	8
66					E	8
65					E	8
64					E	8
63					E	8

to Zone BF7, which is characterized by a high *Betula* content. All the samples from Group D fall into the large Cyperaceae Zone (Zone BF6) but there are five samples at the base of this zone which are classified as Group E samples. The samples that belong to the lower half of Group E coincide with the lowermost zone (Zone BF8) that has been established for this diagram. There is one peculiar group, Group C, that does not seem to fit into any of the established pollen zones. Samples 104, 75 (Group C) and 74 (Group D) appear to be representative of some form of transitional boundary betweeen the pollen zones. For example, samples 74 and 75 are situated in the transitional zone between Zone BF6 and Zone BF7. Sample 94 is probably isolated because it has a higher relative percent of *Alnus* and a slight decrease in Cyperaceae pollen.

There were two discrepancies in the correlation of the cluster groups with the pollen zones. One of these discrepancies has already been mentioned and it is related to the Group E samples. The upper half of the Group E samples have been placed in the major zone designated Zone BF6, although an examination of these samples (especially Ericaceae, *Picea*, *Betula* and Cyperaceae) indicate that the pollen spectra of these samples are more similar to Zone BF8 samples than Zone BF6 samples. However, the differences were not significant and if one takes into account the large unsampled interval between these two zones, then the samples from the upper half of Group E must be placed into Zone BF6.

The other discrepancy is related to the fact that the cluster analysis does not document the subdivision of Zone BF6. This is not a problem if one remembers that the changes in the pollen spectra between Zone BF6a and Zone BF6b are not major changes, and it is quite possible the cluster analysis is not sensitive to the subtle changes.

(b) Upper Bluefish Unit

The results of the cluster analysis of the upper Bluefish unit (Fig. 8 and Table 7) are a little more difficult to interpret. Group A consists of only one sample (6BF1) and is equivalent to pollen Zone 1, which is similar to the present day vegetation. The samples that form Group B are the samples that contained no pollen. The majority of these samples come from the major sterile zone in the upper part of the pollen diagram (Fig. 6), which has been designated as Zone BF2. If we ignore the remaining sterile samples from Group B, we can distinguish three other groups (C, D and E) which can be correlated with the remaining zones established for the rest of the upper Bluefish diagram.

Group C can be correlated to the Gramineae zone (Zone BF3) while Zone BF4b can be equated to the Group E samples. The Group D samples are split into two parts which are equivalent to Zones BF4a and BF4c. Again, as in Zone BF6 from the lower unit, the cluster analysis groups two sets of samples, that have been previously placed in separate zones,

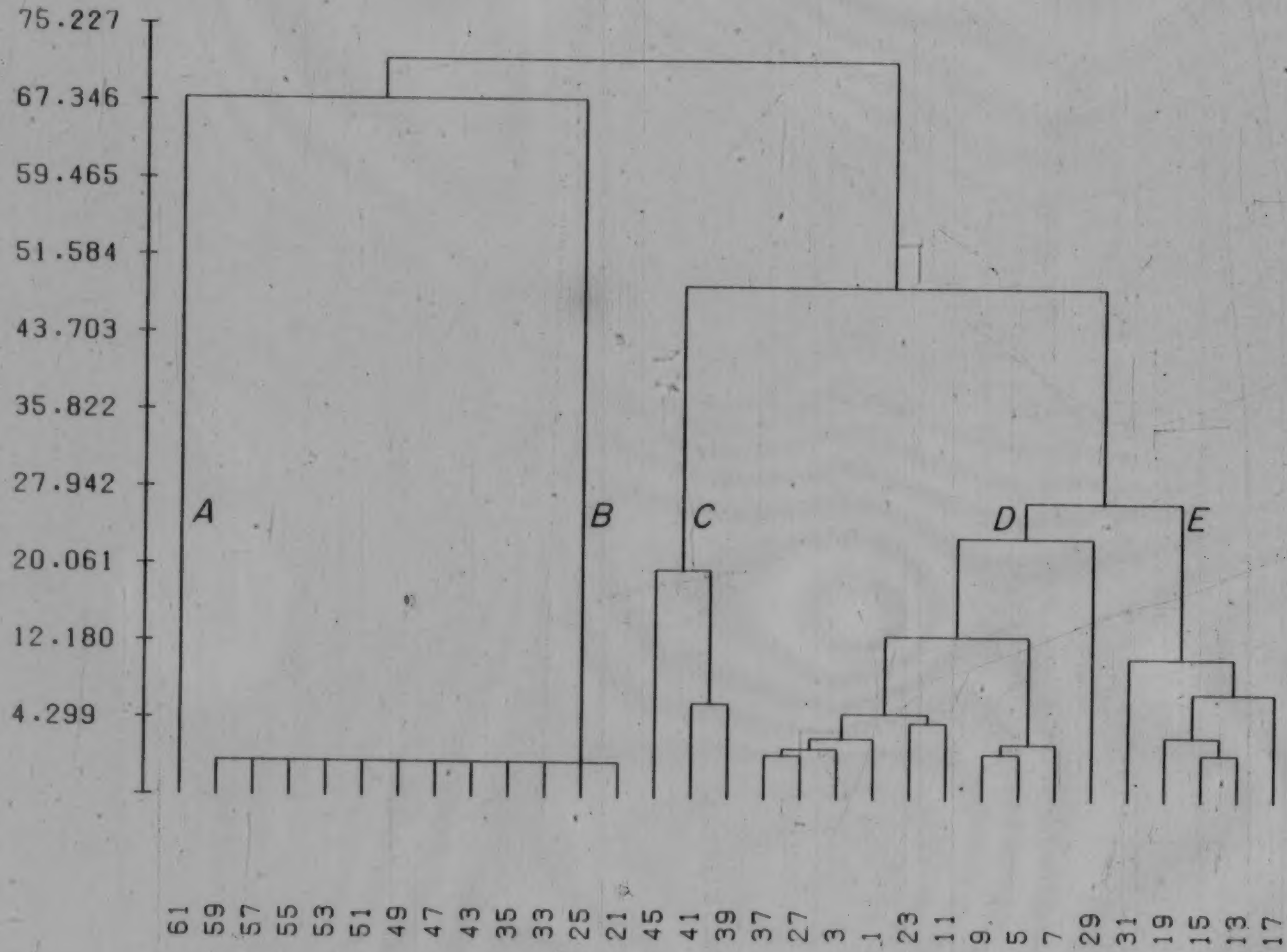

Figure 8: Group Average Cluster Diagram for upper Bluefish unit

TABLE 7: Stratigraphic listing of upper Bluefish unit clusters and equivalent pollen zones

Sample	Clusters A	B	C	D	E	Pollen Zone
61	A					1
59		B				2
57		B				2
55		B				2
53		B				2
51		B				2
49		B				2
47		B				2
45			C			3
43		B				
41			C			3
39			C			3
37				D		4a
35		B				
33		B				
31					E	4a
29				D		4a
27				D		4a
25		B				
23				D		4a
21		B				
19					E	4b
17					E	4b
15					E	4b
13					E	4b
11				D		4c
9				D		4c
7				D		4c
5				D		4c
3				D		4c
1				D		4c

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into one large group. An examination of the pollen diagram does indicate that the major constituents (Cyperaceae, Gramineae, *Artemisia*) of these two sub zones are very similar but the analysis does not pick up the disappearance of the minor herb component in subzone BF4c. This subzone was also established because of the large amount of preQuaternary spores that appear at this level and these spores were not included in the data matrix for the cluster analysis.

Factor Analysis (Principal Component Analysis)

Factor analysis is a statistical technique that is used for discerning patterns (if any) that exist in large amounts of numerical data. The method has been extensively described in the literature (Cattell, 1952, 1965a, 1965b; Rummel, 1965, 1967; Joreskog, Klovan and Reyment, 1976) and has been widely used in research especially the social sciences (eg. Akler, 1964; Banks *et al*, 1965; Russet, 1965, 1967).

There are several different varieties of factor analysis (see Rummel, 1965, 1967; Joreskog *et al*, 1976) and in palynology the most commonly used form is Principal Component Analysis (PCA). PCA is a method used for transforming a given set of variables or principal components (factors) that are orthogonal (uncorrelated) to each other. The method has been described in detail by many authors (Seal, 1964; Harman, 1967; Morrison, 1967; Rummel, 1967; Kim, 1975).

PCA determines the best linear combination of variables that would account for the most variance within the data as a whole, when compared to other linear combinations of variables. The first principal component (Factor 1) is defined as the best linear combination of variables that accounts for the most variance. The second component (Factor 2) is selected because it represents the second best linear combination of variables, under the restriction that this axis is perpendicular to the first principal component. This means that the second axis (Factor 2) is uncorrelated to the first axis (Factor 1) and accounts for "the most residual variance after the effect of the first component is removed," (Kim, 1975:470). This procedure is carried on until all the patterns (variance) within the data have been removed.

Once all the principal components (factors) have been obtained the researcher can generate a set of factor scores for each sample. Factor scores are a theoretical value obtained by multiplying the standardized pollen frequencies by the weight (factor loading) of each variable and summing the products. This information is the most useful to the palynologist, because once you have determined the number of patterns (factors) within the data and which variables (pollen types) affect each factor to the highest degree, you can then plot the factor scores for each sample stratigraphically and observe the fluctuations within each of the pattern (factors) through changes in depth and compare the results with the pollen diagram. Pollen types that did not attain values of 5% or more were combined into larger groups. The reasons for doing this were: (1) Pollen values of less than 5% are not considered numerically significant and therefore contribute very little to the variance (patterns) within the data (Birks, 1974). Although these variables might be important in attempting any paleoecological reconstruction, they do not aid in establishing biostratigraphical patterns. (2) Instead of discarding these variables immediately, they were combined into larger groups to see if, as larger groups, they would make a significant contribution to the patterns within the data. The variables were grouped according to their vegetation classification type, i.e. trees, shrubs, herbs or aquatics. In the lower Bluefish unit, the herb group included all the herbs except Cyperaceae, Gramineae and *Artemisia*, which were treated as separate variables because they attained values of greater than 5%. The aquatic component included *Myriophyllum spicatum*, *Nuphar*, *Potamogeton* and *Typha*. *Larix*, *Pterocarya*, *Tsuga* and *Pseudotsuga* were classified under trees, while the shrub group contained *Shepherdia canadensis*, *Cornus canadensis*, *Elaegnus*, *Lonicera* and *Myrica*. The upper Bluefish herb group was treated in the same manner as the lower Bluefish unit with Cyperaceae, Gramineae and *Artemisia* treated as separate individuals. *Pinus* and *Populus* were grouped under trees, while *Shepherdia canadensis* and *Typha* were treated as individuals because there were no other pollen types of less than 5% that could be grouped with these two variables.

After the initial factor analysis was carried out and the factors and factor scores were examined, it was then decided that the trees and aquatics groups from the lower Bluefish unit, and the trees group, along with the variables *Shepherdia canadensis* and *Typha* would be removed from the data, because they occurred in such small amounts as either a group or an individual that they contributed an insignificant amount of variance to the data as a whole. ~~All~~ the remaining groups, the herb groups from both units and the shrub group from the lower Bluefish unit, were retained in the final analysis.

Pollen types that attained values of greater than 5% were treated as individual variables. The one exception to this pattern occurred in the lower Bluefish unit, where *Picea* and *Pinus* were combined into a group known as Arboreal. This was done because the preservation of the conifers was for the most part very poor and in an effort to circumvent the possibility of misidentification they were treated as one variable. This follows the pattern used in discussing these two variables in the pollen diagram.

The program used for these analyses was a PA 1 factor analysis with a varimax rotation from the Statistical Package for the Social Sciences (SPSS) (Nie *et al*, 1975). A description of the program has been outlined by Kim (1975) and the complete results for the upper and lower Bluefish units are given in Appendices F and G; the factor scores are given in Appendices H and I, and the factor score plots are shown in Figures 9 and 10.

(a) Lower Bluefish Unit

The lower Bluefish unit was combined into eleven variables (see Table 8) and yielded six factors that accounted for 92.4 percent of the total variance.

The plot of factor scores for Factor 1 (Figure 9) show slightly positive values in the lowest part of the section, generally zero or near zero values in the middle part of the column and negative values in the upper part of the section. The factor is dominated primarily, by two variables (*Alnus* and Gramineae) whose loadings show a negative relationship (-0.91 and -0.84 respectively) (Table 8). The variables that indicate significant positive loadings are the Arboreal group (0.65) and to a lesser extent *Corylus* (0.40). The Factor 1 loadings can be compared favourably to the pollen diagram for the lower Bluefish unit. *Corylus* and the Arboreal group (*Picea* and *Pinus*) have their highest relative frequencies in pollen Zones BF7 and BF8 which are at the base of the diagram (see Fig. 5). The significant positive loadings (*Corylus* and the Arboreal variable) for Factor 1 also occur at the base of the section. The negative loadings (*Almus* and Gramineae) on Factor 1 appear in the upper meter of the factor score plot (Fig. 9), and an examination of the

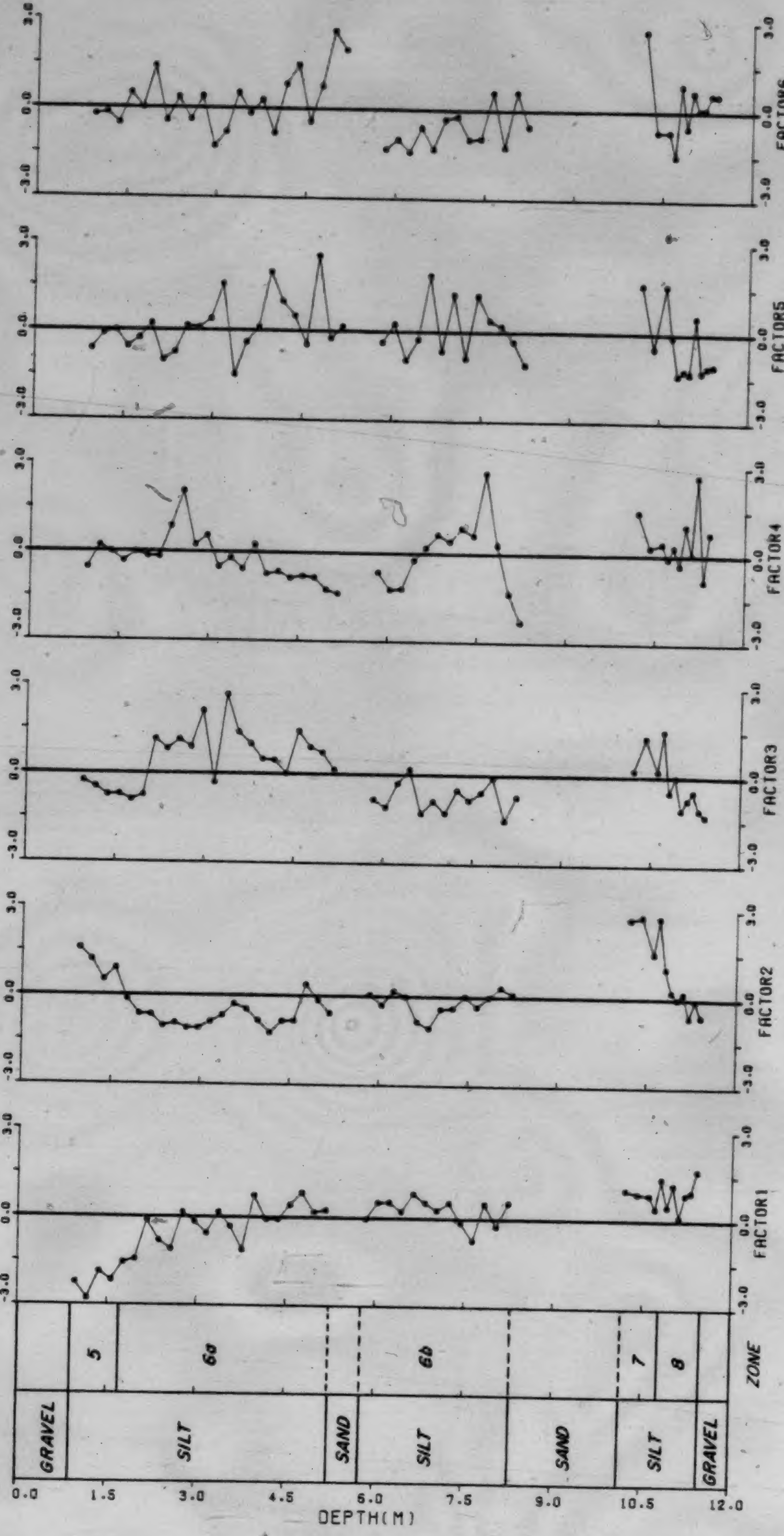

Figure 9: Factor Score Plot lower Bluefish unit

pollen diagram (Fig. 5) also indicates *Alnus* and Gramineae increasing in relative frequency in the upper part of the diagram (Zone BF5). None of the variables affecting Factor 1 play a significant role in the middle part of the section and this is verified by the near zero values for the loadings of these variables in the middle part of Fig. 9.

Factor 2 is loaded heavily by two variables, *Betula* and Cyperaceae (Table 8). The *Betula* variable has a high positive value (0.94), while Cyperaceae shows a high negative value (-0.85) and if the pollen diagram (Fig. 5) is examined this inverse relationship is quite obvious (i.e. where *Betula* is high, Cyperaceae is low and *vice versa*). The factor score plot for Factor 2 (Fig. 9) illustrates two areas with distinct positive peaks (high *Betula*) and these peaks coincide with the two *Betula* highs that occur within the lower Bluefish pollen diagram (Zones BF5 and BF7; Fig. 5). The factor scores for the central portion of the Factor 2 plot have zero or negative values and can be equated with pollen Zone BF 5 (Fig. 6) which is delineated by high percentages of Cyperaceae pollen.

The loadings of Cyperaceae for Factor 3 (Fig. 9) are characterized by two positive peaks, one which occurs at approximately 10.5 meters, the other between 2 and 5 meters. There is only one variable that shows a significant positive loading for this factor and that is *Artemisia* (0.88; Table 8). The herb variable has a positive value (0.46), but this does not carry as much weight as the loading for the *Artemisia* variable. The only pollen type with an important negative loading is the Arboreal group (*Picea* and *Pinus*) which has a value of -0.58. The positive peaks on the factor score plot for Factor 3 (Fig. 9) can be correlated to the higher *Artemisia* percentages that also appear in this part of the pollen diagram (Fig. 5). The negative values in the lower half of the Factor 3 plot can be attributed to the higher relative frequencies of the *Picea* and *Pinus* pollen as well as the lack of *Artemisia* pollen. The negative factor scores on Factor 3 near the top of this unit are most likely due to the reduction of *Artemisia* pollen, because conifers are non-existent in this part of the pollen diagram. The inverse relationship, that is shown to exist in Factor 3, between *Artemisia* and the Arboreal group helps support the division of Zone BF6 into an "a" and "b" subzone (Fig. 5). This zone was originally subdivided because of the appearance of *Artemisia* and disappearance of *Picea* and *Pinus*.

Factor 4 displays three positive peaks which occur at the 11.0, 7.5 and 2 meter marks (Fig. 9). The rest of the factor scores are characterized by loadings that are either negative or zero. This factor is controlled by one variable (Ericaceae) with a high positive loading (0.92) and another variable (*Corylus*) with a lower positive loading (0.55) (Table 8). The positive peaks all coincide with increases in the relative percentage of Ericaceae pollen and to a lesser

TABLE 8
VARIMAX ROTATED FACTOR MATRIX LOWER BLUEFISH UNIT

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6
ARBOREAL	0.65505	-0.02625	-0.58126	0.13090	-0.23192	-0.24030
BET	0.11772	0.94834	-0.07840	0.02863	-0.02457	-0.17885
SAL	0.01526	-0.25172	0.02547	-0.16992	0.01777	0.91609
ALN	-0.91597	0.09868	-0.15489	-0.02429	-0.08170	-0.01172
ERIC	-0.06081	0.16040	-0.13587	0.92030	0.05647	-0.22191
CORY	0.49597	0.32716	-0.22843	0.56393	-0.27608	0.28114
SHRUBS	0.13570	-0.08943	0.17060	-0.01136	0.93820	0.02228
CYPER	0.20106	-0.85418	0.21642	-0.35564	0.06047	0.05171
GRAMIN	-0.84041	-0.08028	0.07117	0.08334	-0.24610	-0.12382
ARTEM	0.03042	-0.26761	0.88823	-0.19171	0.16960	0.00094
HERBS	0.28201	0.39389	0.39599	0.08267	0.46837	0.49334

TABLE 9
VARIMAX ROTATED FACTOR MATRIX UPPER BLUEFISH UNIT

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
PICEA	0.98325	-0.03055	0.01297	-0.07592	0.09352
BET	0.95378	-0.00667	-0.03083	0.07276	0.25961
SAL	0.05837	0.29966	0.17815	0.90943	-0.11265
ALN	0.95524	0.17165	0.00940	0.10539	0.13848
ERIC	0.41635	0.08536	0.04788	-0.10857	0.89069
CYPER	0.04191	0.84721	0.04710	0.39923	0.17719
GRAM	-0.01185	0.09464	0.93764	0.24613	0.02279
ARTEM	-0.01917	0.56562	0.75963	-0.09786	0.05494
HERBS	0.09603	0.80951	0.46553	0.12699	-0.07746

extent the presence of *Corylus* at the base of the pollen diagram (Fig. 5).

The Shrub variable (*Shepherdia canadensis, Lonicera, Elaegnus, Myrica* and *Cornus canadensis*) is the only variable that demonstrates a significant loading (0.94) on Factor 5 (Table 8). The positive peaks in the upper half of the Factor 5 score plot are probably related to the presence of *Shepherdia* pollen in this part of the diagram (Fig. 5). The lower half of the plot illustrates peaks that can be correlated to peaks in *Myrica* pollen.

Factor 6 is heavily loaded by the *Salix* variable (0.92). The plot of the factor scores indicates that there is no real pattern in this Factor, and this is quite evident when the frequency of *Salix* in pollen diagram is examined. *Salix* occurs thoughout the pollen diagram in relatively abundant amounts and does not show any particular trends that might be useful in helping zone the pollen diagram.

As an aid in zoning the pollen diagram only the first three factors would appear to be of any use in verifiying the pollen zones established in the previous chapter. Factor 1 helps delineate Zones BF5 and BF8 based on the loadings for *Alnus*, Gramineae and the Arboreal variables. Pollen zones BF6 and BF7 (Cyperaceae and *Betula* zones) can be confirmed with the aid of Factor 2, while Factor 3 is useful in dividing pollen Zone BF6 into an upper (BF6a) and lower (BF6b) Zone based on the differences in *Artemisia* pollen percentages versus the percentage of *Picea* and *Pinus* Arboreal group.

(b) Upper Bluefish Unit

The upper Bluefish unit was grouped into nine variables which yielded five factors (see Table 9) that accounted for 95.2 percent of the total variance.

The factor scores for Factor 1 do not show much variation from zero except for the high positive value at the surface of the column and three very small positive peaks in the centre of the plot (Fig. 10). The variables with high positive loadings are *Picea* (0.98), *Betula* (0.95) and *Alnus* (0.95). Ericaceae is also characterized by a positive loading (0.41) although this is not as significant as the other three variables (Table 9). The Factor 1 profile (Fig. 10) coincides with highs in the relative percentages of the four variables, especially the major positive peak at the top of the column, which can be correlated with Zone BF1 (*Picea - Betula - Alnus*) (see Fig. 6).

Factor 2 is characterized by positive values for Cyperaceae (0.84) and herbs (0.80) (Table 9). *Artemisia* also indicates a positive loading (0.56) but the weight of this variable is not as great as the loadings for the other two variables. A comparison of the factor scores for Factor 2 (Fig. 10) with the pollen diagram for the upper Bluefish unit (Fig. 6) demonstrates with the exception of two samples

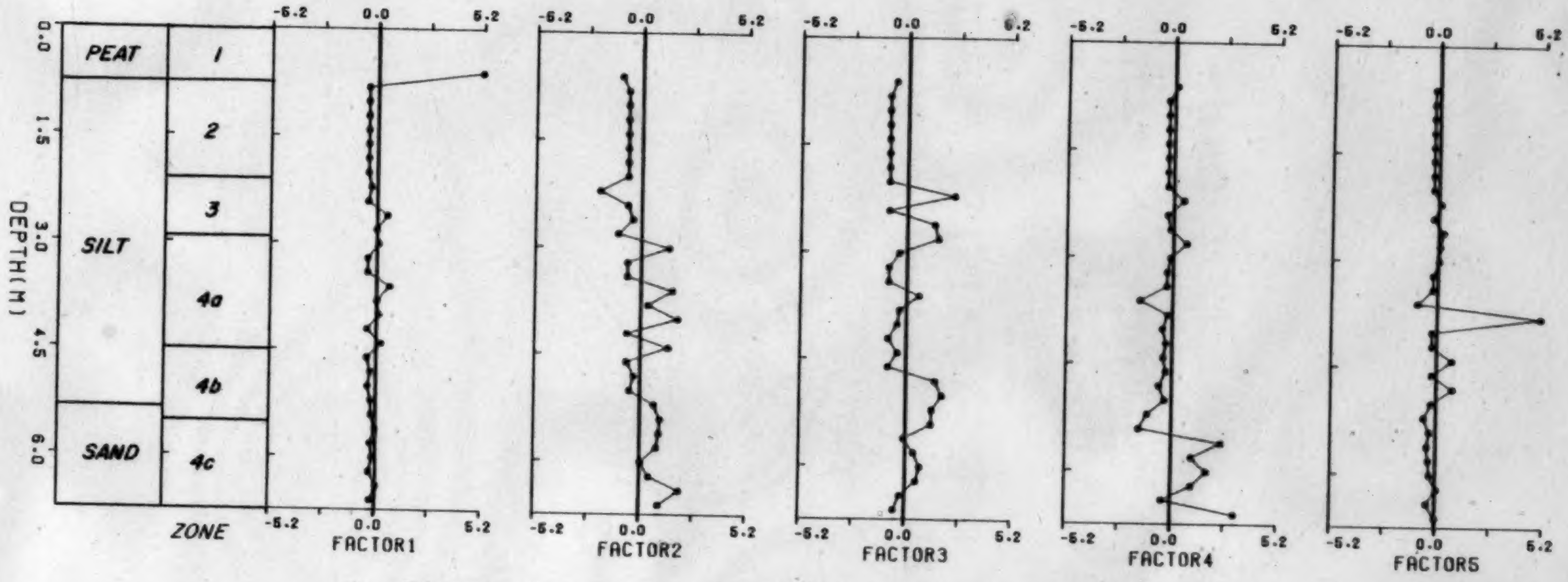

Figure 10: Factor Score Plot upper Bluefish unit

(17, 19), that where the factor scores are positive, the pollen frequencies for Cyperaceae and the herb component (especially Chenopodiaceae - *Amaranthus*, Liguliflorae, Tubuliflorae, Caryophyllaceae and *Arabis*) also attain their highest level (Zone BF4; Fig. 6).

Gramineae has the highest positive loading (0.93) on Factor 3, followed by *Artemisia* (0.75) and to a lesser degree the herb component (0.53). An examination of the factor score plot (Fig. 10) shows that the positive peaks can be correlated with the areas of the pollen diagram (Fig. 6) that illustrate relatively high percentages of grass pollen (Zone BF3) as well as zones that contain high grass and *Artemisia* pollen (Zone BF4b). Zones BF4a and BF4c can be recognized between the areas that show strong positive peaks, and are characterized by factor scores that are around zero.

The patterns for Factor 4 can be described by a positive loading of the *Salix* variable. The factor score plot (Fig. 10) draws a positive peak at the base of the column, and this coincides with the relatively higher percentages of *Salix* pollen that are present at the base of the pollen diagram (Zone BF4a; Fig. 6).

The last significant factor (Factor 5) contains a major positive peak and two minor positive peaks located at the centre of the diagram (Fig. 10). The only variable that shows a significant loading on the factor is Ericaceae

(0.89) and the increases in the pollen frequency of this variable are synchronous with the appearance of the positive peaks in the factor score plot (Fig. 10).

With the exception of Factor 5, all the factors are useful in confirming the zones established for the upper Bluefish unit. Factor 1, which is loaded heavily by *Picea, Betula* and *Alnus*, produces a pattern which would support Zone BF1. Pollen Zone BF3 (Gramineae zone) can be justified on the basis of the patterns illustrated by Factor 3. The combination of Factors 2, 3 and 4 helps substantiate the establishment of Zone BF4, as well as delineating the subzones BF4a, BF4b and BF4c.

Chapter VI. Interpretations and Discussion

Zone BF 8

A pollen sample documented by Matthews (1970), from Edmonton, Alberta shows an arboreal pollen spectra that is very similar to the fossil arboreal component described in Zone BF 8. The surface sample, which contains 15% pine, 25% spruce, and 15% birch pollen, was collected in a spruce stand containing a few larches, but no pines. The pine pollen is derived from pine trees that exist on dry sites within the immediate area (Matthews, 1970:249). There are differences, however, between the fossil pollen spectra described from Zone BF 8 and the surface sample documented by Matthews. The major dissimilarity occurs in the non-arboreal component, where Cyperaceae pollen occurs in significantly higher quantities in Zone BF 8 (30 - 35%), whereas, Matthews' surface sample contains less than 10% sedge pollen. This suggests that Cyperaceae was a fairly important component of the local vegetation of the study site area.

If you ignore the *Pinus* pollen found in Zone BF 8, the fossil pollen record is very similar to the surface pollen spectra described by Birks (1977) and Rampton (1971a) from sedge swamps located in spruce forests. The pine pollen present in Zone BF 8 never exceeds 10%, suggesting that pine was probably part of the regional vegetation, but not present in the vicinity of the study site. The relative precent of *Betula* pollen is also more abundant in Zone BF 8 than in either of the surface pollen spectra described by Birks and Rampton. If the *Betula* pollen was derived from shrub birch, as was the case with the surface pollen results of Birks and Rampton, this would suggest that the forest was probably more open than the two modern analogues. Matthews (1974a) has described a fossil pollen record from Cape Deceit, Alaska, which is very similar to the surface pollen spectra described by Birks and Rampton. He suggests his pollen record is representative of a forest tundra vegetation, although he does state that it is difficult to "conceive an analogous contemporary woodland or forest tundra community being represented by such a small percentage of birch pollen" (1974a:1327). The pollen spectra from Zone BF 8 does, however, have 15 - 20% birch pollen and therefore could be conceived of as a forest tundra type vegetation.

The presence of *Corylus* and *Pinus* pose some interesting questions concerning the age of this zone. The modern day northern limit of pine is some 200 kilometers to the south while *Corylus* occurs near the southern boundary of the boreal forest. The fact that these two species occur so much further to the south today suggests the climate must have been milder during this time. This premise is further supported by Matthews (1970), who has described a fossil pollen record from the Lost Chicken mine site, Alkaska. The site is believed to be pre-Wisconsin in age. The sample was taken from frozen silts, and contains 15% *Pinus* pollen, as well as, significant amounts of *Picea* (25%) and *Betula* (20%) pollen. Matthews suggests that the "presence of pine in the Lost Chicken region is evidence of a warmer climate, even warmer than during the early Holocene," (Matthews, 1970:249). Matthews further states that "the Lost Chicken sample probably represents an interglacial,"(1970:249). *Corylus* is also known to be part of the Arcto-Tertiary flora, and could be a remnant of that flora. This could suggest that the base of the lower Bluefish unit maybe early Pleistocene in age.

There are only four other published pollen records from Alaska and the Yukon Territory that are believed to be Illinoian or older. Colinvaux (1964), has described a pollen core from Imuruk Lake on the Seward Peninsula, western Alaska. In his report, Colinvaux suggests that the base of his core contains the complete Yarmouthian pollen record from this area, which he describes as being predominantly a tussock tundra type of vegetation very similar to the modern vegetation of the area. During the Illinoian, the vegetation becomes more steppe like and this is replaced by another modern type of tussock tundra during the warmer Sangamon. Matthews (1974a) has suggested that Colinvaux's ecological interpretations in this part of the core are incorrect. Matthews states that the record does not represent a series of alternating glacial and interglacial environments and that the entire Yarmouthian and Illinoian pollen record of

Imuruk Lake is primarily a steppe tundra environment. Furthermore, Matthews believes that the bottom two thirds of the core represents a glacial environment (steppe tundra). If Matthews' interpretations are correct then the base of Colinvaux's core probably does not correlate with the base of the alluvial section at the study site. Whatever the age of the core or the ecological interpretation (modern tundra vs. steppe tundra) the vegetational record at the base of the Imuruk Lake core is quite different from the base of the section at the Bluefish study site.

The only other pre-Illinoian - Illinoian pollen record comes from Cape Deceit, Alaska (Matthews, 1974a). This site just north of Imuruk Lake is a colluvial section as opposed to a lake or bog core. The base of the section is believed to be Cromerian (this is based on faunal assemblages) in age. The Cromerian interval as described in England, is a series of glacial and interglacial fluctuations occuring 400,000 - 900,000 years ago. During the Cromerian interglacial intervals at Cape Deceit, the pollen spectra is interpreted as a forest or forest tundra type vegetation. The earliest interglacial intervals were dominated by spruce, while larch became the dominant tree during the later interglacials. The glacial intervals are characterized by pollen spectra that suggest the presence of steppe tundras (Matthews, 1974a). Cape Deceit was occupied by an open spruce forest during a pre-Illinoian interglacial which was replaced during the Illinoian by a herbaceous tundra.

The herbaceous tundra was in turn succeeded by modern tundra during the Sangamon.

The vegetational record described from the base of the Cape Deceit section (Cromerian series) indicates a forest or forest-tundra environment that is similar to the record established for the base of the Bluefish section. The difference, however, is the absence of larch in Zone BF 8 at Bluefish.

The last two pre-Illinoian pollen records have been documented by Lichti-Federovich (1972,1974). Her work was based on the analysis of sediments taken from a number of alluvial sections along the Porcupine and Old Crow Rivers (see Fig. 2). Her Zone Va is interpreted as a pine-spruce birch forest with alder and hazel present as shrubs. This is replaced by a more open pine-spruce-birch forest with less herb dominated treeless communities (Zone Vb). The vegetational history during Zone V is very similar to the pollen spectra described in Zone BF 8 from the study site. The one major difference is the larger amount of *Picea* and *Pinus* that is present in the pollen records established by Lichti-Federovich. This difference can be accounted for if one takes into consideration where the study sites are located. Most of Lichti-Federovich's sections are located in the middle of the Old Crow/Porcupine Lake basins. Here the arboreal component will have a much greater influence on the pollen spectra, since there are no local or extra local pollen sources. The Bluefish study site on the other hand, is situated on the edge of the basin and therefore under greater influence of the local vegetation i.e. the greater abundance of Cyperaceae pollen.

From the previous discussion it would appear that the vegetation at the Bluefish site during Zone BF 8 time was probably an open forest type with spruce and to a lesser extent pine being the dominant trees. Birch was also present although it is not known if it was as trees or shrubs. Hazel, alder and willow were also sporadically present as the major shrub components. The relative abundance of heaths suggests the forest was open. The dominance by Cyperaceae pollen suggests sedge fen or meadow vegetation. While the lack of grass pollen also implies a fen as opposed to a meadow. *Sphagnum* and *Selaginella selaginoides* are also common and the presence of *S. selaginoides* supports the interpretation of moist woodland conditions. The climate of the area at this time would have to have been warmer with higher precipitation than at present.

Zone BF 7

The pollen spectra from this zone is similar to Zone 4, the *Betula* zone, described by Rampton (1971) from Antifreeze Pond; Zone I from Tuktoyaktuk 5 (Ritchie and Hare, 1971); pollen assemblage type IV from the Old Crow - Porcupine region (Lichti-Federovich 1972,1974) and pollen zone HL 3 documented by Cwynar (1980) from Hanging Lake. Livingstone's

(1955) Zone II from arctic Alaska and Ager's (1976) Zone 2 from the lakes in the Tanana Valley, Alaska also documents a birch pollen zone. As Lichti-Federovich (1972) and Cwynar (1980) have pointed out there is no easy modern analogue for this *Betula* pollen zone. And it has usually been described as a shrub tundra vegetation dominated by dwarf birch (see above references).

Zone BF 7 at Bluefish, no doubt also represents a shrub tundra environment dominated by shrub birch, with a substantial sedge - *Artemisia* - herb community on the better drained sites. The reduction of conifer pollen especially spruce probably means that the treeline was retreating to the south, although it was still close enough to contribute to the regional pollen rain. Alders, willows and ericads were also present, but perhaps confined to valley bottoms and close to stream banks where there was more moisture. Because of the reduction of conifer pollen and spores from *Sphagnum* and *Selaginella selaginoides*, and the interpreted change from an open forest to a tundra type vegetation, the climate must have become cooler with less precipitation. The presence of *Botrychium* is especially puzzling as it usually occurs in alpine meadows or on grassy slopes (Hulten, 1968). However, there does not appear to be enough evidence to suggest a meadow grass type vegetation.

Neither Colinvaux (1964) or Matthews (1974a) document a similar birch zone around the Sangamon or Illinoian. Both authors describe tundra type vegetations at this time but neither contain pollen spectra which have 50% birch pollen. Lichti-Federovich described a *Betula* zone for pollen assemblage type IV which appears immediately after the first glacial episode (possibly Illinoian) in the area.

Zone BF 6

This zone is the major zone from the lower Bluefish unit. It is dominated by Cyperaceae pollen and the pollen spectra show similarity to the modern surface samples obtained from sedge-moss tundra environments, (Ritchie and Lichti-Federovich, 1967; Rampton, 1971a). Birch pollen frequencies are higher in the Bluefish spectra, however. There is also a very strong resemblance to the pollen spectra described by Schweger (1979) from three alluvial exposures along the Koyukuk and John River in Central Alaska. Schweger (1979:17) describes these as representing:

> a treeless tundra vegetation with much reduced shrub component...The very high frequencies of Cyperaceae pollen implies a sedge rich vegetation; sedge fens, pioneer sedge seres and sedge rich meadows must have dominated the floodplain vegetation.

However, unlike Schweger's record *Betula* and *Sphagnum* appear to have been more abundant around the Bluefish exposure.

Jan Janssens (written communication) has analysed detrital layers from the lower portion (Zone BF 6b) of this zone for fossil bryophytes. Seven well preserved taxa were recovered, these include *Calliergidium pseudostramineum*, *Calliergon richardsonii*, *Cratoneuron filicinum*, *Dicranum groenlandicum*, *Ditrichum flexicaule*, *Drepanocladus* spp. and *Scorpidium scorpioides*. These species are found in a number of environments including tundra and fen type environments as well as bogs, rivers, wet meadows and lakes, but their presence is not incompatible with the pollen taxa that have been described from this zone.

Using the above information the following vegetational reconstruction is suggested for Zone BF 6b. The local vegetation was probably an open shrub tundra type vegetation with Cyperaceae being the dominant ground cover occurring both in sedge fens and sedge seres as well as being dominant in the upland regions. *Sphagnum* mosses were probably also fairly common. Shrub birch would be relatively common but not in the same quantity as Zone BF7, being more sporadic. Alder also appears to be slightly more abundant than in previous zones. The presence of *Myrica* type pollen indicates that this shrub was probably present in the fens or in other areas that were relatively swampy or contained small shallow bodies of water. The relative abundance of spruce pollen suggests that spruce trees were part of the regional vegetation but not abundant near the study site. Ericads were probably common in the more mesic sites. An examination of the habitat characterization of the minor pollen taxa (Table 10) indicates that the majority of the pollen types were found on dry gravelly or sand areas or along stream edges. The herb component including *Potentilla* type, *Papaver*, Caryophyllaceae, *Arabis* type, *Saxifraga tricuspidata* type and *Thalictrum*. *Ribes*, *Mitella nuda* type and *Epilobium* were also probably present along stream edges.

The upper half of Zone BF6 (BF6a) is also dominated by Cyperaceae pollen indicating that it was still the dominant ground cover. But, with the reduction in birch and alder pollen and an increase in *Artemisia* pollen, the local vegetation would appear to have become even more tundra-like with the shrub component much reduced. The consistent but low percentages of *Shepherdia canadensis* pollen suggest that this shrub must have been part of the shrub component albeit in small quantities. The reduction in Ericaceae and *Sphagnum* pollen, and the increase in *Artemisia* suggest a drier climate, or better drained substrate. There appears to be little evidence for trees even in the regional vegetation and what little conifer pollen that is present is probably the result of long distant transportation. This suggests that the treeline had retreated further to the south, as the climate became cooler and drier. The minor herb component appears to be a little richer in diversity when compared to 6b, but this could also be a reflection of the reduction of arboreal pollen rain making the herb component more visible because the herb pollen is no longer masked by the arboreal component. Much of the herb component is still the type of vegetation you would expect to find in alluvial environments (*Arabis* type, *Potentilla* type, Caryophyllaceae, *Thalictrum*

TABLE 10: Habitat Characterization of Minor Pollen Taxa

TAXA	Hulten's Description
Allium	Meadows, Grassy Slopes
Anemone	Meadows, Grassy Mountain Slopes, Dry Forests, Thickets, Snowbeds, Heaths, stony slopes, DRY ROCKY SLOPES, SCREE Slopes
Antenaria	MEADOWS, RIVER FLATS, ALPINE SLOPES, SANDY SOIL ON TUNDRA, MEADOWS ON TUNDRA
Arabis	MOIST STONY PLACES, SCREE SLOPES, ALPINE MEADOWS, DRY ROCKY PLACES
Caltha palustris	MOIST PLACES, BOGS, PONDS,
Cardamine	GRAVELLY PLACES BELOW MELTING SNOW, MOIST PLACES ALONG CREEKS, THICKETS
Circaea	WOODS
Claytonia	WET PLACES, STONY SLOPES IN THE MOUNTAINS, SNOW BEDS, GRAVEL BARS
Cornus canadensis	SPRUCE AND BIRCH FORESTS
Dryas	GRAVEL BAR, HEATHS, WET FORESTS
Elaegnus	DRY SLOPES, GRAVEL BARS
Epilobium	MEADOWS, FORESTS, RIVER EDGE, WET TO MOIST AREAS
Galeopsis	WASTE PLACES
Gentiana	MEADOWS, BOGS, DRY SLOPES
Lonicera	WOODS
Maianthemum	MOIST WOODS, MEADOWS, ALDER THICKETS
Mitella nuda	ALONG STREAM BOGS
Myrica cf gale	SWAMPS, SHALLOW WATER
Myriophyllum spicatum	PONDS, SHALLOW WATER, OR WET SOIL
Nuphar	PONDS, SHALLOW WATER, OR WET SOIL
Papaver	SANDY GRAVELLY SOIL

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TABLE 10(con't)

TAXA	Hulten's Description
Plantago	WET PLACES, SALT MARSHES, OPEN WASTE AREAS, SALINE SOIL
Polygonum amphibium	NO DATA
Polygonum aviculare	WET PLACES
Polygonum bistorta	MEADOWS, HEATHS, TUNDRA BOGS
Polemonium	WET MEADOWS, STREAM EDGES, DRY SANDY TO ROCKY AREAS
Potamogeton	PONDS, SHALLOW WATER, OR WET SOIL
Potentilla	DRY OPEN ROCKY TO SANDY AREAS, STREAM EDGES
Ranunculus	SHALLOW WATER, WET MUD, PONDS, POOLS, WET MUDDY SHORES, WET MEADOWS, WET TUNDRA, SNOW BEDS, BOGS, PEATY SOIL
Ribes	MOIST WOODS, ALONG STREAMS, ROCKY SLOPES IN THE LOWLANDS
Rosa acicularis	WOODS, HEATHS, TUNDRA BOGS, THICKETS
Rubus	WET MEADOWS, WOODS, RIVER EDGE
Rumex-Oxyria	WET PLACES, SNOW BEDS IN MOUNTAINS, AND TUNDRA
Saussurea	DRY PLACES ON TUNDRA IN THE MOUNTAINS
Saxifraga hirculus	BOGS AND MEADOWS
Saxifraga oppositifolia	CALCAREOUS ROCKS
Saxifraga tricuspidata	DRY SANDY PLACES, ROCK CREVICES, RIDGES COMMON IN THE MOUNTAINS
Taraxacum	MEADOWS, MOIST PLACES IN MOUNTAINS, WASTE PLACES, ALPINE SLOPES, TUNDRA
Thalictrum	ALPINE MEADOWS, STONY SLOPES IN THE MOUNTAINS, MEADOWS, WOODS
Typha	PONDS, SHALLOW WATER, OR WET SOIL
Valeriana	MOIST PLACES

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, *Saxifraga tricuspidata* type) especially along stream edges and on sandy gravelly soils (Table 10).

Zone BF 5

The pollen spectra from Bluefish Zone BF 5, likewise does not appear to have any easily recognizable analogues. A similar pollen spectra occurs in the pollen record from Cape Deceit (Matthews, 1974a). The spectra from above and below peat 5 of the Deering Formation are different in that the alder percentages are lower while the grass component is at least 10% higher than the Bluefish spectra. Matthews describes this spectra as representing a grassy tundra with shrub birches. He further states that alder was probably abundant regionally, and this would indicate an amelioration of the climate (1974a:1377).

It would appear from the pollen spectra that there was a good rich shrub tundra present at this time, with birch and alder dominating an abundant shrub layer. The open areas were probably covered by sedge and grass, with *Sphagnum* moss also being abundant. The presence of *Pterocarya* is unusual becuase it no longer exists in Canada and was last part of the Arcto-Tertiary flora that has been described by Wolfe (1972). Its presence could be the result of long distance transportation probably from Asia or else it is redeposited material. There were no conifers present in the local vegetation and based on the very low percentages the regional landscape was undoubtedly treeless and what little conifer pollen there is, is related to long distance transportation.

The increase in *Betula, Alnus* and *Sphagnum* along with the large amounts of *Pediastrum* suggest that there was an amelioation in the climate with temperatures rising and precipitation increasing throughout the area during the time of deposition of Zone BF 5. The presence of large amounts of *Pediastrum* plus the consistent appearance of *Isoetes* tend to indicate that there was probably a body of water of some form at, or very close to, the site.

The amelioration of the climate, that is suggested by the pollen record, correlates with the general time stratrigraphic framework of the study site section. Zone BF 5 occurs just below the middle Bluefish unit, which is thought to represent the Sangamon Interglacial and therefore the climate of the region was probably getting warmer and more moist.

These four pollen zones (BF5 to BF8) record the vegetational and climatic changes that occured during the deposition of the lower Bluefish unit sediments. The oldest pollen zone (BF8) indicates an open spruce-pine forest was present in the area. The open forest was replaced by a birch shrub tundra (BF7) rich in sedges and *Artemisia*. A shrub tundra also characterizes subzone BF6b, but now Cyperaceae dominates, although shrub birch and alder were present but with reduced frequency. An increase in *Artemisia* and further reduction in the arboreal and shrub components indicates that the vegetation of subzone BF6a was open tundra. Finally, one sees in zone BF5 the reappearance of birch-alder shrub tundra. The four zones witness vegetation changes from open woodland to open tundra and back to shrub tundra.

The vegetational history suggests, the region initially experienced greater preciitation and warmer temperatures than exist today (BF8), followed by increasingly colder temperatures and much more arid conditions (BF6,7). Finally, there is a return to a warmer and more moist climate (BF5).

It possible the climatic oscillations from warm to cold and back to warm again might be used to establish a possible time stratigraphic framework for the lower Bluefish unit. This will be discussed in the final chapter.

Zone BF 4

The pollen spectra from Zone BF 4 represents the classic "Herb Zone" that has been described throughout Eastern Beringia by numerous workers. This zone is dominated by Gramineae, Cyperaceae and *Artemisia* and was first described by Livingstone (1955) from his studies in Arctic Alaska. The interpretations of this zone have been quite varied and have ranged from a grassland type environment described by Colinvaux (1964, 1967b) at the Seward Peninsula, to a fell-field and sedge-moss environment outlined by Rampton (1971a) from Antifreeze Pond (Zone 1, 3a, 3b). The most common interpretation is that the herb zone represents a steppe-tundra environment. This has been suggested by Matthews at Cape Deceit (1974a) and the Isabella basin (1974b), by Ager (1975) for his pollen zone 1 from the Tanana Valley, by Lichti-Federovich (1972) in her pollen assemblage Type III from the Old Crow Basin and for the pollen record described by Schweger (1976) for the Epiguruk II alluvial sections along the Kobuk River, Alaska. Similar herb zones have also been described by Terasmae and Hughes (1966) from the Ogilvie Mountains and by Ritchie (1972, 1977) from the MacKenzie delta and Tuktoyaktuk Peninsula, N.W.T.. The most recent documentation of the herb zone and the most thorough discussion of its interpretation is by Cwynar (1980) from Hanging Lake in the northern Yukon. Although the interpretations may be varied, the one common demominator about the herb zone is that it occurred thoughout Eastern Beringia in the late Pleistocene during the last Wisconsin advance and early post glacial. This supports the earlier conclusion that Zone BF 4 is of late Pleistocene and probably late Wisconsin. The base of the Zone maybe 30,000 to 35,000 B.P.(Rampton, 1971a; Cwynar, 1980).

There are no convincing modern analogues for the herb zone although as Cwynar (1980) points out there "are numerous surface pollen spectra from alpine, subarctic and arctic regions that have two of the herb dominants, Gramineae and Cyperaceae, in abundance," (1980:67) but he also points out that "these taxa, together with *Artemisia* and *Salix*, are of limited indicator value because they are represented by many species of varying geographical, as well as ecological, affinities." (1980:67)

Zone BF 4 has been subdivided into three subzones based on the changes in ratio of Cyperaceae-*Artemisia* pollen and the presence of pre-Quaternary spores. It is possible, however, that these differences may not indicate changes in vegetation and that the difference in the subzones might be the result of changes in lithology within this zone. The boundary between subzones BF 4a and BF 4b occurs where there is a marked change in lithology from samples that are 90% sand to samples that are predominantly silt (contain less than 10% sand). It might be possible that the change in Cyperaceae-*Artemisia* ratio is a result of a grain size change and is not related to a vegetational change. Subzone BF 4c is differentiated from BF 4b by the presence of pre-Quaternary spores as well as a relative decrease in *Artemisia* along with a relative increase in Cyperaceae. However, an examination of the indeterminate categories indicates that there is a substantial increase in indeterminate tricolpate-tricolporate pollen, which upon re-examination could very well be badly preserved *Artemisia* grains, and therefore *Artemisia* might be underrepresented in this pollen zone. Based on these assumptions it is possible that the entire Zone BF 4 shows very little vegetational change and that the only significant change is the appearance of large amounts of pre-Quaternary spores. The origin of these spores will be discussed in Zone BF 2.

Using the above information the vegetation of the region during this time (probably the late Wisconsin) was a steppe tundra vegetation dominated by Cyperaceae , Gramineae and *Artemisia*. There were few, if any, shrubs with birch and willow being the most common types. Liguliflorae type and *Arabis* type were the most prevalent of the minor herbs with Chenopodiaceae type, Tubuliflorae type, *Potentilla*, Caryophyllaceae, *Saxifraga hirculus* type, *Polemonium* and *Phlox* also consistently present. Many of the herbs associated with Zone BF 4 are found in alluvial environments and on river beds (see Table 10) which coincides with the general setting of the study site at the time of deposition.

The region must have experienced arctic cold and very arid conditions during this time and the climate was probably very similar to the climate experienced in a polar desert.

Zone BF 3

This zone is unlike any other zone in the pollen diagrams. The presence of 60 - 80% Gramineae pollen has not been documented as far as I know in a modern surface pollen spectrum from North America. *Artemisia* is still relatively common but Cyperaceae eventually disappears altogether.

There is no mention of a similar type of zone in any fossil pollen record from North America. Lichti-Federovich (1974) describes a zone (pollen assemblages type III, Zone E) from the Porcupine River (Site 8, see Fig. 2) which contains between 40 - 80% grass, however this zone also contains 10 - 30% spruce and 10 - 30% sedge. The pollen spectra from Zone BF 3 indicates that the vegetation was predominantly a treeless and shrubless grassland with *Artemisia* also present. It seems unlikely that there were no other herbs but this is probably due to an over-representation of grass pollen which would mask the minor herb taxa.

There are no extensive grasslands found in the northern Yukon today. This is due in large part to the presence of permafrost, which prevents the grasses from developing their extensive underground root system. However, the pollen spectra from zone BF 3 suggests, that grasslands may have exsisted in this part of the Yukon in the late Wisconsin. Furthermore, the presence of grasslands implies the absence of a shallow permafrost layer. This means that the soils were warmer and better drained than they are at the present.

Zone BF 2

This zone is the major sterile fossil pollen or spore zone that occurs near the top of the upper Bluefish unit. This zone is dominated by pre-Quaternary spores and occurs in approximately the same stratigraphic position as the major sterile zone that was found in the Porcupine River section described by Lichti-Federovich (1974). Lichti-Federovich's sterile zone occurs between pollen zones E and F just below the Holocene peats found at the top of the alluvial section. This sterile zone, along with the other sterile zones in the upper Bluefish unit, are somewhat problematical because they create a gap in the vegetational record. There are a number of possibilities that can be used to explain why this sterile fossil pollen zone exists at the Bluefish study site.

Originally it was thought that the presence or absence of pollen might be related to changes in grain size and pollen sedimentation throughout the section, but analysis of the sediment proved to be inconclusive (see Fig. 10 and Appendix C). Samples that were high in sand content contained abundant pollen, while samples that were predominantly silt showed no particular pattern as to why they contained pollen or were sterile. Most of the samples in the middle silt unit from the upper Bluefish unit contained the same ratios of sand-silt-clay and while some of these samples contained pollen, just as many samples were sterile. Therefore, it seemed unlikely that grain size had any bearing on the presence or absence of pollen.

The calcium carbonate content also appeared to have no effect on the presence or absence of pollen. If the calcium carbonate content increases, you create alkaline conditions in the sediment. Deposition of pollen into highly alkaline

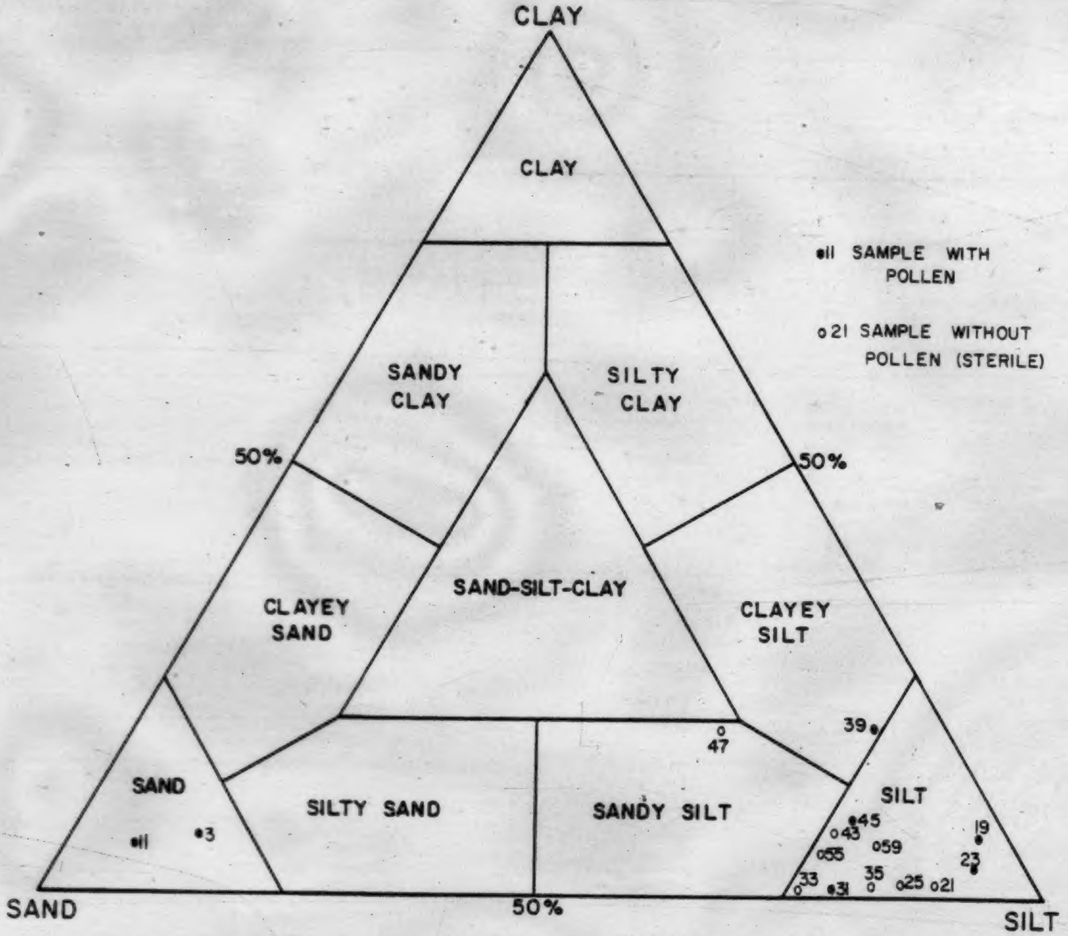

Figure 11: Grain Size Analysis and Textural Classification (after Shepard, 1954)

conditions is detrimental to the pollen grain and it will likely be destroyed. Although the carbonate content did show a very slight increase as one progressed up the section it does not appear to have affected the samples in relation to there being pollen present or absent in the sample, especially since there are sterile zones in the lower parts of the silt unit.

Even if grain size and carbonate content did explain the major sterile zone as well as the other sterile zones, the presence of the pre-Quaternary spores which begin to appear with the first appearance of the sterile zones, must be explained in terms of determining the source from which these spores might be derived. One possible source is material slumped in or eroded from surrounding pre-Quaternary bedrock. Rapid deposition of sediment from a debris flow for example, would also dilute the pollen rain. An examination of aerial photographs failed to reveal potential sources from which this slumped material might come from, especially areas that contained Devonian rocks, as the spores appear to be primarily Devonian in age. It would help if more sedimentological work could be carried out on the area in an aid to determining direction of source of sediment and from this trace back to an original source. Another alternative is that the pre-Quaternary spores are related to the advance and retreat of the last Wisconsin ice sheet. It is possible that the spores are derived from bedrock (possibly near the Peel River) which has been ground up by advancing ice and deposited as outwash by the glaciers. The spores would continue to be deposited during the retreat of the ice as material was released from the receeding mass of ice. The problem with both of the above suggestions is how do you explain the alternating sterile-pollen-sterile zones in the lower half of the silt unit (Zones BF 3 and BF 4a). There is one other problem with the second suggestion and that is, if the ice sheets were responsible for the deposition of the pre-Quaternary spores, as well as, the sterile zones and if the major sterile zone along with the spores are present until the upper contact of the silt unit with the Holocene peats there must have been little if any sediment deposition at the study site from the time of retreat of the glaciers until the onset of widespread peat development during the Holocene. The other possibility of course is that there is a major hiatus in the sedimentary record between the overlying peats and the underlying silts. This would mean that you could have rapid deposition of the silts, followed by a period of erosion and eventually the development of the overlying peats.

Oxidation and/or mechanical deterioration of the pollen grains are two alternative ways in which the pollen may have been destroyed. This would be especially true in a near shore-deltaic environment similar to the one that existed at the study site while the upper Bluefish unit was being deposited. Consequently, if the entire upper unit was laid down as an near shore-deltaic sequence, one would expect that the above two processes would have been continually at work destroying the pollen grains being deposited in these sediments. Therefore, the entire upper Bluefish unit would be expected to contain little or no pollen, or at the very least a large number of degraded pollen grains. However, Zones BF 3 and BF 4, which are part of the upper Bluefish unit, contain abundant identifiable pollen grains.

Perhaps, the best explanation lies in the type of climatic conditions that might have existed in the region during the late glacial and early post glacial. If the climate was relatively harsh(e.g. cold and fairly dry), there might have been very little vegetation growing in the area resulting in a decreased production of the pollen rain. Alternatively, severe climatic conditions may have created a situation more suitable for vegetative reproduction and therefore, similarly reduced the pollen rain being contributed to the fossil pollen record.

Zone BF 1

The pollen spectra from this zone is very similar to fossil pollen spectra described by Rampton (1971a) from Antifreeze pond (Zone 6) and by Ager (1976) in Tanana Valley (Zone 3b). Lichti-Federovich (1972, 1974) also describes a *Picea-Betula-Alnus*-Ericad zone at the top of her sections from the Old Crow Basin and the Porcupine River. The pollen spectrum from Zone BF 1 is very similar to the present day vegetation with spruce being the dominant tree. Birch was also present but whether it was as a tree or shrub is difficult to tell. Based on other pollen records in the Northern Yukon it seems as if birch was more common as a shrub. Alder was also present as were members of the heath family. This suggests that the vegetation was similar to that of the present day northern boundary of the spruce forest. It is difficult to say when this transition from tundra type vegetation to forested conditions took place. Almost all the pollen records from the Yukon and eastern Alaska demonstrate a *Betula* zone between the tundra zone and the forested zone. This shrub birch tundra zone is missing from the Bluefish study site. Rampton (1971) and Ager (1976) both document the appearance of the spruce forest after 6,000 B.P. Ritchie and Hare (1971) indicate a similar spruce forest around the Tuktoyaktuk Peninsula between 8,500 and 5,500 B.P. Therefore all one can say is that the invasion of the area by the spruce forest must have occurred sometime after 8,500 years before present.

Pollen zones BF 1 to BF 4 document the vegetational and climatic changes that took place during the deposition of the upper Bluefish unit sediments. A steppe-tundra vegetation dominated by the presence of Cyperaceae, Gramineae and *Artemisia* characterizes zone BF 4. There were few, if any, shrubs, with birch and willow being the most common types. Changes in the ratio of Cyperaceae, Gramineae and *Artemisia*, as well as the appearance of pre-Quaternary spores allowed Zone BF 4 to be subdivided into three subzones. The steppe-tundra was replaced by a vegetation that is predominantly a treeless, shrubless grassland (BF3). *Artemisia* is still relatively common, but Cyperaceae decreases towards the top of the zone eventually disappearing. Zone BF 2 is a major sterile fossil pollen or spore zone that occurs near the top of the upper Bluefish unit. Changes in sedimentation rates, as well as variations in the fossil pollen rain are two of the possible reasons for the presence of this zone. Finally, there is the appeareance of a Boreal Forest that is very similar to the present day vegetation. Spruce was the dominant tree, with birch and alder common in the shrub layer.

Pollen zones BF 4 and BF 3 suggest the region must have experienced a polar desert type climate with arctic cold and extreme aridity. The presence of grassland (BF 3) would indicate the absence of a shallow permafrost layer, suggesting the soils were warmer and better drained than todays soils. Finally, we have climatic conditions (BF 1) that are very similar to the present day climate.

Chapter VII. Summary

Over the past ten years the Northern Yukon has been the focus of extensive research dealing with Quaternary paleoecological and paleoenvironmental reconstructions. In an attempt to establish a Quaternary vegetational record for the Bluefish Basin and to add further information to the reconstruction of the paleoecology of the Northern Yukon, an alluvial section (67° 23′ W latitude, 140° 21.5′ N longitude) that has been exposed by the downcutting of the Bluefish River, was sampled for pollen analysis. The study section was chosen because it was located on the western edge of the Bluefish Basin, and would allow documentation of the near shore sedimentary facies as well as the near shore pollen spectra. The results obtained could then be compared to other workers who have documented the geology and pollen history for the interior parts of the Bluefish Basin.

The stratigraphy can be summarized as follows. The partially exposed underlying bedrock is a brecciated dolomite that is Paleozoic (possibly Devonian) in age. A lignite coal seam overlies the dolomite and is considered to be Tertiary (Oligocene) or earliest Pleistocene in age. The remaining sediments are all Quaternary in age and maybe subdivided into three major units. (1) A lower Bluefish unit, which is characterized by organic valley fill alluvium, is thought to have been deposited prior to the Sangamon Interglacial. The basal sediments might possibly be earliest Pleistocene in age. This unit was sampled for pollen. (2) A middle Bluefish unit, which was not analysed for pollen, is a channel fill deposit that was probably laid down during the Sangamon Interglacial. (3) An upper Bluefish unit documents the Late Wisconsin Glaciation and is represented by shallow water near shore lacustrine and deltaic deposits. A peat layer that overlies the section is considered to be Holocene in age. The upper unit was sampled for pollen analysis.

Pollen analysis revealed the lower Bluefish unit contained abundant, well preserved fossil pollen. Over sixty different pollen taxa were observed along with a variety of mosses, ferns and algae. There were no pre-Quaternary spores present in the lower unit. Pollen was abundant in the basal parts of the upper Bluefish unit. However, the amount of pollen gradually decreased as you proceeded up the section, eventually becoming sterile near the top of the unit (Zone BF 2). The upper Bluefish unit contained fewer pollen taxa (about forty different taxa) and the general level of preservation was much poorer, when compared with the lower Bluefish unit. Pre-Quaternary spores were present throughout the upper Bluefish unit, reaching their highest levels in Zone BF 2. The overlying peat unit yielded large amounts of well preserved pollen (Zone BF 1).

The pollen data suggested the establishment of eight pollen zones. Pollen zones BF 5 to BF 8 outline the vegetational and climatic changes that occurred during the deposition of the lower Bluefish unit sediments. The vegetational and climatic changes that took place during the deposition of the upper Bluefish unit are documented by pollen zones BF 1 to BF 4. The oldest pollen zone (BF 8) indicates an open spruce-pine forest was present in the area. Birch, hazel, alder and willow were also present as the major shrub components. The open forest was replaced by a birch shrub tundra (BF 7) rich in sedges and *Artemisia*. Zone BF 7 also shows a relative decrease in conifer pollen suggesting that the treeline was retreating to the south. A shrub tundra also characterizes subzone BF 6b, but now Cyperaceae is the dominant ground cover. Although shrub birch and alder were present it is with reduced frequency. An increase in *Artemisia* and further reductions in the arboreal and shrub components indicates that the vegetation of subzone BF 6a was an open tundra. In Zone BF 5, one sees the reappearance of a good rich shrub tundra with birch and alder dominating an abundant shrub layer. The open areas were probably covered with sedges and grasses. A steppe-tundra vegetation dominated by the presence of Cyperaceae, Gramineae and *Artemisia* characterizes Zone BF 4. There were few, if any, shrubs, with birch and willow being the most common types. The pollen spectra from Zone BF 4 represents the classic " Herb Zone " that has been described throughout Eastern Beringia by numerous workers. The steppe tundra was replaced by a vegetation that is predominantly a treeless, shrubless grassland. *Artemisia* is still relatively common but Cyperaceae has almost completely disappeared. Zone BF 2 is a major sterile fossil pollen or spore zone that occurs near the top of the upper Bluefish unit. Changes in sedimentation rates, mechanical and chemical destruction of the pollen grains, as well as variations in the fossil pollen rain are just some of the possible reasons for the presence of this zone. Finally, there is the appearance of the Boreal Forest, that is very similar to the present day vegetation. Spruce was the dominant tree, with birch and alder common in the shrub layer.

The vegetational history suggests, the region initially experienced greater precipitation and warmer temperatures than exist today (BF 8), followed by increasingly colder temperatures and much more arid conditions (BF 6,7). Eventually, there is a return to a warmer and more moist climate (BF 5). Pollen zones BF 4 and BF 3 suggest the region must have once again experienced a climate with arctic cold and extreme aridity. The presence of grassland in Zone BF 3 would indicate the absence of a shallow permafrost layer, suggesting the soils were warmer and better drained than todays soils. Finally, we have climatic conditions (BF 1) that are very similar to the present day climate.

The lack of a tighter chronological framework for the study site section is one of the problems that exist in this thesis. However, with the use of the pollen data and the inferred climatic changes, along with the small amount of dating control available, it is possible to suggest a time stratigraphic framework (see Table 11). As previously mentioned (see Chapter 3) the near shore lacustrine and deltaic deposits of the upper Bluefish unit have been correlated with the youngest glaciolacustrine sediments found in the central parts of the Bluefish Basin. This would suggest the upper unit was deposited during the Late Wisconsin Glaciation. A Late Wisconsin age is further supported by the pollen record, which indicates the Bluefish River study site was covered by a 'herbaceous' vegetation (Zones BF 3 and BF 4) at the time of deposition of the upper unit. Research by other workers has shown that this 'herb' zone was present throughout the interior Yukon and Alaska in the Middle and Late Wisconsin. The overlying peat layer has been correlated to the extensive peat layer, that developed throughout the Bluefish Basin during the Holocene.

The middle Bluefish unit is a channel fill deposit that has been correlated to other fluvial and deltaic sediments, which exist at similar stratigraphic levels in other parts of the Bluefish Basin. The presence of spruce logs within this unit along with a > 54,000 radiocarbon date suggest this unit is older than most of the Middle Wisconsin and is probably Early Wisconsin or Sangamon in age. A Sangamon age is supported by a number of workers who believe the climate was warm enough at this time for the tree line to re-advance

Table II: Summary Table of Pollen Zones, Vegetation, Stratigraphy and Climate.
(Climatic interpretations should be read from bottom to top)

	Pollen Zone	Vegetation	Suggested Age	Stratigraphy	Precipitation, Temperature
Upper Bluefish Unit	1	Boreal Forest	Holocene	Peat	Moist, Warm
	2	———	Late Wisconsin	Silt	———
	3	Grassland	Late Wisconsin	Silt	Dry, Colder
	4a,b	Steppe Tundra	Late and Middle Wisconsin	Silt	Very Dry and Arctic Cold
	4c	Steppe Tundra		Sand	
Middle Bluefish Unit			Sangamon	Gravel	
Lower Bluefish Unit	5	Rich Shrub Tundra	Early Sangamon	Silt	Moist, Warm
	6a	Steppe Tundra	Illinoian	Silt	Dry, Cold
	6b	Open Shrub Birch Tundra	Illinoian	Silt	Drier, Cool
	7	Shrub Birch Tundra	Pre-Illinoian	Silt	Moist, Cooler
	8	Open Pine Spruce Forest	Pre-Illinoian	Silt	Moist, Warm
				Sands and Gravels	

from the south.

The most difficult unit to try and assign some type of dating control is the lower Bluefish unit. The valley fill alluvium sediments that comprise the lower unit were correlated to fluvial and deltaic deposits in other parts of the Bluefish Basin (see Chapter 3). Unfortunately, because there is such poor dating control on the age of these sediments, they could range in age anywhere from pre-Illinoian to Sangamon. However, the climatic oscillations that can be inferred from the pollen record for the lower Bluefish unit can allow one to propose the following time stratigraphic table (see Table 11). The warm and moist climate that is suggested by the presence of a rich shrub tundra (BF 5) at the top of the lower unit and just below the middle Bluefish unit (which is thought to be Sangamon), indicates the upper part of the lower unit is probably Sangamon in age. The colder and more arid climatic conditions that are inferred by the open shrub-tundra (BF 6b) and the steppe-tundra(BF 6a) are probably indicative of the Illinoian Glaciation. The shrub birch tundra that characterizes Zone BF 7 suggests that the climate in the Bluefish Basin was warmer and more moist than the climate that existed for Zone BF 6. The replacement of a shrub-birch tundra (Zone BF 7) by a steppe-tundra vegetation (Zone BF 6) infers a detioration of the climate. This climatic change is probably indicative of the onset of the Illinoian Glaciation, and therefore means, that Zone BF 7 is pre-Illinoian in age. The oldest pollen zone (Zone BF 8) indicates climatic conditions that were warmer and more moist than at any other time, including today. The sediments from the lower most parts of the lower Bluefish unit are ,therefore, probably pre-Illinoian and maybe Early Pleistocene.

The increasing amounts of information being gathered in the Bluefish Basin will eventually lead to a better time stratigraphic framework. A better understanding of the stratigraphy, improved dating control and further paleoecological research will all hopefully lead to a greater understanding of the Quaternary paleoenvironmental reconstructions for the Northern Yukon.

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APPENDIX A

List of plant species collected from the Bluefish River study site

- *Anemone narcissiflora* L. subsp. *interior*
- *Anemone parviflora*
- *Arctostaphylos rubra*
- *Aster sibiricus*
- *Astragalus alpinus* L. subsp. *alpinus*
- *Betula glandulosa*
- *Caltha palustris* L. subsp. *arctica*
- *Cardamine pratensis* L. subsp. *angustifolia*
- *Carex aquatilis* L. subsp. *aquatilis*
- *Carex capillaris*
- *Carex scirpoidea*
- *Carex vaginata*
- *Cnidium cnidiifolium*
- *Draba cinera*
- *Epilobium angustifolium* L. subsp. *angustifolium*
- *Equisetum arvense*
- *Equisetum scirpoides*
- *Eriophorum vaginatum* L. subsp. *vaginatum*
- *Galium boreale*
- *Hedysarum alpinum* L. subsp. *americanum*
- *Ledum palustre* L. subsp. *decumbens*
- *Ledum palustre* L. subsp. *groenlandicum*
- *Melandrium taimtrense*
- *Oxycoccus microcarpus*
- *Petasites frigidus*
- *Potentilla fruticosa*
- *Rhododendron lapponicum*
- *Rosa acicularis*
- *Rubus chamaemorus*
- *Salix alaxensis* L. subsp. *alaxensis*
- *Salix arbusculoides*
- *Salix glauca* L. subsp. *acutifolia*
- *Salix lanata* L. subsp. *richardsonii*
- *Saussurea angustifolia*
- *Seneccio yukonensis*
- *Solidago multiradiata* Ait. var. *multiradiata*
- *Stellaria longipes*
- *Toefieldia coccinea*
- *Vaccinium uliginosum* L. subsp. *alpinum*
- *Vaccinium vitis-idaea* L. subsp. *minus*

APPENDIX B

Paleoenvironmental Studies, University of Alberta

Palynology Laboratory

Processing sediments for Pollen

1. Weigh out 10-15 g. of sediment into 100 ml. beaker. Add 25 ml. of 10% NaOH, stir well with wooden stirring rod, boil gently with constant stirring on hot plate for 5 minutes. Filter immediately through a fine screen, (coarse screen if sediment is very peaty) into 150 ml. beaker, retaining sand and coarse particles in original beaker. Add 10 ml. distilled water to coarse fraction of sediment remaining in beaker, stir, then swirl for 60 seconds. Allow to settle for exactly 30 seconds, pour supernatent suspension onto screen. Repeat with a second portion of 10 ml. distilled water. Wash the fine sediment on the screen with a few drops of water. Transfer contents of beaker to Nalgene centrifuge tubes, balance tubes by means of centrifuge-tube balance, centrifuge, decant supernatent liquid. Wash sediment in bottom of centrifuge tube with 10 ml. of water to which a few drops of 10% NaOH have been added, balance tubes, centrifuge, decant. Repeat if necessary until supernatent liquid is no longer heavily coloured by humates.
2. Add a few drops of conc. HCL to the sediment, stir well. When the initial reaction has subsided, add a little more HCL, stir again. Continue adding HCL until no

further effervescence occurs, balance tubes, centrifuge. Decant.

3. Add about 15 ml. of $ZnBr_2$ soln. (sp. gr. 1.8-2.0), stir. Balance centrifuge tubes. Stopper tubes with rubber stopper, shake gently, and release any accumulated pressure. Stopper again, shake for exactly 3 minutes, then centrifuge for 20 minutes. Carefully filter with suction the zinc bromide solution through glass filter paper in Nalgene Buchner funnel. Do not discard the filtrate: pour the filtrate into the bottle labelled "Used $ZnBr_2$". Roll up the filter paper on which the pollen is now deposited, place the wad in a clean Nalgene centrifuge tube.
4. CAUTION: USE MASK, GLOVES and APRON. DO NOT BREATHE VAPOURS. Cautiously add a few drops of hydrofluoric acid (HF), swirl. When the violent reaction subsides, add a little more HF, swirl again. Add a total volume of 15-20 ml. HF, stir with a clean wooden stirring rod, loosely stopper with Nalgene stoppers, heat in boiling water bath on hot plate for 1 hour. Allow to stand at room temperature in hood overnight.
5. Centrifuge, decant, add 10 ml. conc. HCL, stir thoroughly, allow to boil in water bath on hot plate for 5 minutes, cautiously stirring once during the 5 minute period. Centrifuge while still hot, decant. Repeat process at least six times.
6. (Transfer if desired to 15 ml. glass centrifuge tube).

Wash with 10 ml. distilled water, centrifuge, decant.

Wash with 10 ml. glacial acetic acid, centrifuge, decant.

7. Acetolysis, etc, (as for peat samples).

Processing Peat for Pollen

1. Place peat sample in 100 ml. beaker. Add 20 ml. of 10% NaOH, stir well with wooden stick, boil gently with constant stirring on hot plate for 5 minutes. Allow to cool, pour off supernatent through fine screen into 150 ml. beaker, retaining most of the peat in the original beaker. Wash peat in beaker with several 10 ml. portions of distilled water, pouring off supernatent each time through screen. Transfer the liquid to Nalgene centrifuge tube, centrifuge, decant. Wash material in bottom of tube with water to which a few drops of 10% NaOH have been added. Centrifuge, decant. Repeat if necessary until supernatent is straw coloured.
2. Wash with 10 ml. glacial acetic acid (transfer if desired to 15 ml. glass centrifuge tubes).
3. CAUTION: make up acetolysis mixture. Measure out the desired multiple of 9 ml. of acetic anhydride into 125 ml. flask. To this, add cautiously in several portions with swirling, the desired multiple of 1 ml. conc. H_2SO_4.
4. Add 10 ml. of acetolysis mixture to centrifuge tube. Stir well with clean stick. Heat for 3-5 minutes in boiling water bath on hot plate. Cool. Centrifuge, decant.
5. Wash with 10 ml. glacial acetic acid. Centrifuge, decant.
6. Wash with 10 ml. distilled water. If it is desired to

stain grains, add several drops of Safranin-O at this stage. Centrifuge, decant.

7. Wash with water to which a few drops of 10% NaOH have been added. Centrifuge, decant.
8. Wash with 10 ml. of 98% ethyl alcohol. Centrifuge, decant.
9. Wash with 10 ml. of acetone. Centrifuge, decant.
10. Suspend the pollen in a few mls of acetone, pour into vial, wash tube with a few drops of acetone, pour into vial. To vial add 2-3 drops of glycerol, allow to evaporate overnight. If necessary add more glycerol and mount on microscope slide.
11. Alternatively, add a few drops of glycerol to the pollen in the centrifuge tube and transfer to the vial by means of a disposable pipette. Mount on slide.

APPENDIX C

Grain size analysis results used for plotting on Figure 4

Sample Number	Sand(%)	Silt(%)	Clay(%)	Soil Texture Classification	Textural Ternary* Diagram	Pollen/ Sterile
59	6.0	80.7	13.3	Silty loam	Silt	Sterile
55	5.8	75.1	19.1	Silty loam	Silt	Sterile
47	23.5	58.2	18.3	Silty loam	Sandy Silt	Sterile
45	8.8	77.0	14.2	Silty loam	Silt	Pollen
43	7.3	76.0	16.7	Silty loam	Silt	Sterile
39	6.8	74.9	18.3	Silty loam	Clayey Silt	Pollen
35	0.8	82.5	16.7	Silty loam	Silt	Sterile
33	0.6	75.2	24.2	Silty loam	Silt	Sterile
31	0.7	79.3	20.0	Silty loam	Silt	Pollen
25	1.2	85.5	13.3	Silty loam	Silt	Sterile
23	2.1	92.9	5.0	Silt	Silt	Pollen
21	0.8	89.2	10.0	Silt	Silt	Sterile
19	1.8	91.5	6.7	Silt	Silt	Pollen
11	88.4	7.4	4.2	Sand	Sand	Pollen
3	81.2	13.8	5.0	Sand	Loamy Sand	Pollen

*Textural Ternary Diagram Classification after Shepard (1954)

APPENDIX D

List of Pollen Percentages (Data Matrix) for the Lower Bluefish Alluvial Unit - each pollen type is assigned the following number:

Picea - 1
Pinus - 2
Larix - 3
Betula - 4
Tsuga - 5
Pseudotsuga - 6
Pterocarya - 7
Salix - 8
Alnus - 9
Ericaceae - 10
Corylus - 11
Lonicera - 12
Elaegnus - 13
Shepherdia canadensis - 14
Cornus canadensis - 15
Myrica - 16
Cyperaceae - 17
Gramineae - 18
Artemisia - 19
Chenopodiaceae-*Amaranthus* - 20
Tubuliflorae - 21
Liguliflorae - 22
Compositae:
    - *Saussurea* - 23
    - *Helianthus* type - 24
Ranunculaceae:
    - *Caltha* type - 25
    - *Anemone* type - 26
    - *Ranunculus* type - 27
    - Undifferentiated - 28
Thalictrum - 29
Rosaceae:
    - *Potentilla* type - 30
    - *Dryas* type - 31
    - *Rubus chamaemorus* - 32
    - Undifferentiated - 33
Caryophyllaceae - 34
Polygonaceae:
    - *Bistorta* type - 35
    - *Amphibium* type - 36
    - *Aviculare* type - 37
Rumex-*Oxyria* - 38
Saxifraga:
    - *Tricuspidata* type - 39
    - *Oppositifolia* type - 40
    - *Hirculus* type - 41
cf. *Mitella nuda* - 42

Ribes - 43
Umbeliferae - 44
Cruciferae:
  - *Arabis* type - 45
  - *Cardamine* type - 46
  - Undifferentiated - 47
Onagraceae:
  - *Epilobium* - 48
  - *Circea* - 49
Portulacaceae:
  - *Claytonia* type - 50
Gentianaceae:
  - *Gentiana* type - 51
Scrophulariaceae - 52
Leguminosae - 53
Labiatae:
  - *Galeopsis* type - 54
Papaveraceae - 55
Valeriana - 56
Plantago - 57
Polemonium - 58
Liliaceae:
  - Undifferentiated - 59
  - *Maianthemum* type - 60
  - *Allium* type - 61
Potamogeton - 62
Typha - 63
Myriophyllum spicatum - 64
Nuphar - 65

Sample No.	Grains Counted	Pollen Type 1	2	3	4	5	6	7	8	9	10	11	12
108	221	0.0	1.8	0.0	33.9	0.0	0.0	0.5	3.2	28.0	6.7	0.0	0.0
107	228	0.0	0.4	0.9	29.8	0.0	0.0	0.4	3.0	26.7	8.3	0.0	0.0
106	213	1.9	1.4	0.9	24.8	0.0	0.0	2.8	2.8	21.5	7.9	0.0	0.0
105	267	1.1	0.0	2.3	28.4	0.0	0.0	0.0	5.2	25.2	7.4	0.0	0.0
104	253	1.1	0.0	4.3	17.3	0.0	0.0	0.0	3.9	24.5	8.6	0.0	0.0
103	228	0.0	0.0	2.6	14.4	0.0	0.0	0.0	7.8	15.7	6.5	0.0	0.0
102	245	1.2	0.8	2.4	14.6	0.0	0.0	0.0	3.6	9.3	6.5	0.0	0.0
101	235	0.4	0.8	0.8	9.4	0.0	0.0	0.0	5.1	12.8	9.8	0.0	0.0
100	247	0.0	0.4	2.0	13.4	0.0	0.0	0.0	4.0	12.1	14.2	0.0	0.0
99	255	2.7	0.0	3.9	9.0	0.4	0.4	0.0	5.9	8.6	7.8	0.0	0.0
98	256	0.8	0.0	1.6	11.7	0.0	0.0	0.0	2.3	6.3	7.4	0.0	0.0
97	308	1.9	0.0	1.6	15.9	0.3	0.0	0.0	3.6	13.6	5.5	0.0	0.0
96	262	0.4	0.0	1.1	12.2	0.0	0.0	0.0	6.1	5.7	4.9	0.0	0.0
95	247	1.2	0.4	0.0	18.6	0.0	0.0	0.0	4.9	12.9	4.9	0.0	0.0
94	222	3.2	0.0	0.9	9.9	0.0	0.0	0.0	4.9	21.2	6.8	0.0	0.0
93	267	5.6	0.4	1.1	13.5	0.0	0.0	0.0	3.4	5.6	4.1	0.0	0.0
92	265	2.3	0.8	0.0	8.3	0.0	0.0	0.0	7.2	8.3	3.4	0.0	0.0
91	254	1.2	1.5	2.8	10.2	0.0	0.4	0.0	7.9	6.3	3.1	0.0	0.0
90	235	4.3	2.6	1.3	11.9	0.0	0.0	0.0	4.3	4.7	2.9	0.0	0.0
89	229	0.9	2.2	0.4	18.3	0.0	0.0	0.0	5.2	3.9	3.5	0.0	0.0
88	276	2.5	0.0	0.0	18.5	0.0	0.0	0.0	11.2	4.4	2.2	0.0	0.0
87	256	1.5	0.8	0.8	11.3	0.0	0.0	0.0	8.9	8.6	1.9	0.0	0.0
86	303	8.9	3.6	0.7	24.4	0.0	0.0	0.0	1.9	10.2	6.6	0.0	0.0
85	254	4.7	5.9	1.2	22.8	0.0	0.0	0.0	3.1	8.7	5.1	0.0	0.0
84	299	8.0	3.3	0.3	28.8	0.0	0.0	0.0	2.0	4.7	5.0	0.0	0.0
83	254	3.5	1.6	0.4	20.9	0.0	0.4	0.0	1.9	9.1	6.3	1.2	0.0
82	243	11.9	4.5	0.0	16.9	0.0	0.0	0.0	2.5	4.5	9.5	0.0	0.0
81	234	8.9	5.6	0.0	11.5	0.0	0.0	0.0	3.8	8.9	9.8	1.3	0.0
80	265	9.8	1.9	0.8	24.5	0.0	0.0	0.0	5.7	5.7	11.3	0.0	0.0
79	223	8.1	5.8	0.0	19.7	0.0	0.0	0.0	1.8	8.5	10.3	2.2	0.0
78	228	7.9	2.3	0.4	24.6	0.0	0.0	0.0	2.6	9.7	11.4	0.0	0.0
77	242	3.3	1.2	0.0	19.8	0.0	0.0	0.0	4.9	11.6	14.9	3.7	0.0
76	263	11.4	0.4	0.0	25.5	0.0	0.0	0.0	2.3	5.7	9.9	0.4	0.0
75	296	5.7	5.1	0.7	19.6	0.0	0.0	0.0	5.4	19.3	4.1	0.3	0.0

Sample No.	Grains Counted	Pollen Type 1	2	3	4	5	6	7	8	9	10	11	12
74	240	8.3	1.7	1.3	26.7	0.0	0.0	0.0	3.8	3.3	0.4	0.0	0.0
73	225	1.3	1.8	0.0	43.6	0.0	0.0	0.0	6.7	3.6	10.7	5.3	0.0
72	227	2.2	4.9	0.0	50.7	0.0	0.0	0.0	1.8	4.9	9.6	2.6	0.0
71	216	3.2	7.4	0.0	38.4	0.0	0.0	0.0	2.8	2.8	10.6	0.9	0.0
70	249	0.8	3.6	0.0	53.4	0.0	0.0	0.0	1.2	7.6	9.6	1.2	0.0
69	321	8.4	2.2	0.0	36.8	0.0	0.0	0.0	5.6	3.4	7.8	5.0	0.0
68	245	9.8	3.8	0.0	26.5	0.0	0.0	0.0	3.8	6.1	6.5	1.2	0.0
67	243	12.3	7.8	0.0	20.6	0.0	0.0	0.0	4.9	7.0	8.6	4.9	0.0
66	267	7.5	2.3	0.0	27.3	0.0	0.0	0.0	4.9	4.9	7.9	1.1	0.4
65	229	12.7	3.9	0.0	17.9	0.0	0.0	0.0	3.9	3.9	14.4	4.8	0.0
64	253	11.9	4.7	0.8	24.1	0.0	0.0	0.0	6.3	3.2	3.2	2.8	0.0
63	220	19.9	3.6	0.0	14.5	0.0	0.0	0.0	5.4	2.3	8.6	3.6	0.0

Sample No.	Pollen Type 13	14	15	16	17	18	19	20	21	22	23	24	25	26
108	0.0	0.0	0.0	0.0	10.8	10.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
107	0.0	0.0	0.0	0.4	12.2	14.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4
106	0.0	0.0	0.0	0.5	21.5	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
105	0.0	0.0	0.0	0.0	17.2	9.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
104	0.0	0.0	0.0	0.0	31.2	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
103	0.0	0.8	0.0	0.0	38.5	8.7	0.8	0.0	0.0	0.0	0.0	0.0	0.8	0.0
102	0.0	0.0	0.0	0.0	46.9	6.1	4.4	0.0	0.0	0.8	0.0	0.0	0.0	0.0
101	0.0	0.0	0.0	0.0	44.5	7.7	3.4	0.0	0.0	0.0	0.4	0.0	0.8	0.0
100	0.0	0.8	0.0	0.0	35.6	8.9	4.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0
99	0.0	0.8	0.0	0.0	47.0	3.3	5.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0
98	0.0	1.6	0.0	0.0	48.4	8.2	8.2	0.0	0.0	0.4	0.0	0.0	0.4	0.0
97	0.0	1.9	0.0	0.3	45.5	5.5	3.9	0.0	0.0	0.0	0.0	0.0	0.4	0.0
96	0.0	0.0	0.0	0.0	48.1	6.5	8.8	0.0	0.0	0.4	0.0	0.0	0.0	0.0
95	0.0	0.4	0.4	0.0	40.1	5.7	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
94	0.0	0.9	0.0	0.0	32.9	7.2	6.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0
93	0.0	1.1	0.4	1.1	49.1	2.6	6.4	0.0	0.0	0.0	0.0	0.0	1.5	0.0
92	0.0	1.9	0.0	0.0	51.3	5.7	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
91	0.0	1.2	0.0	0.0	49.2	5.9	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sample No.	Pollen Type													
	13	14	15	16	17	18	19	20	21	22	23	24	25	26
90	0.0	0.9	0.0	0.0	48.5	6.8	7.2	0.0	0.0	0.4	0.0	0.0	0.0	0.0
89	0.0	2.6	0.0	0.0	40.2	1.7	5.7	0.0	0.0	0.0	0.0	0.0	1.7	0.0
88	0.4	0.4	0.0	0.0	42.4	5.1	5.4	0.4	0.4	0.4	0.0	0.0	0.0	0.0
87	0.0	0.8	0.0	0.0	49.6	2.7	3.9	0.0	0.0	0.0	0.0	0.0	0.4	0.0
86	0.0	0.0	0.0	0.3	33.0	6.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.8	0.0	0.0	42.1	2.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.0
84	0.0	0.0	0.0	0.0	39.5	5.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
83	0.0	0.0	0.0	0.4	44.1	5.1	1.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0
82	0.0	1.2	0.0	0.8	39.9	2.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	0.0	0.0	0.0	0.0	41.9	3.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	1.5	32.1	3.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79	0.0	0.0	0.0	0.0	35.4	4.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	0.0	0.0	0.0	1.3	29.4	5.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	0.0	0.0	0.0	1.2	22.9	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	0.0	0.0	0.0	0.8	33.1	4.6	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	29.1	2.7	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
74	0.0	0.0	0.0	0.0	46.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
73	0.0	0.0	0.0	1.8	12.0	1.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
72	0.0	0.4	0.0	0.0	7.9	3.1	3.5	0.0	0.0	0.0	0.4	0.0	0.0	0.0
71	0.0	0.4	0.0	1.4	16.6	2.8	2.8	0.0	0.0	0.4	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.8	7.2	3.6	5.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0
69	0.0	0.0	0.0	0.0	26.5	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	0.0	0.0	0.0	0.0	33.6	6.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67	0.0	0.0	0.0	0.0	26.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66	0.0	0.0	0.0	0.8	31.5	6.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.0	28.8	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
64	0.0	0.0	0.4	0.0	33.9	5.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
63	0.0	0.0	0.0	0.0	32.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sample No.	Pollen Type													
	27	28	29	30	31	32	33	34	35	36	37	38	39	40
108	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0
107	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0

Sample No.	27	28	29	30	31	32	Pollen Type 33	34	35	36	37	38	39	40
106	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
104	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
103	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
102	1.2	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
101	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.8	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.8	0.0
98	0.4	0.0	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
97	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96	0.0	0.0	0.4	1.9	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0
95	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.4	0.0
94	0.0	0.0	0.9	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
93	0.0	0.0	0.0	0.7	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
92	0.0	0.0	0.4	1.9	0.0	0.0	1.1	0.4	0.0	0.0	0.0	0.0	0.0	0.4
91	0.0	0.0	0.0	0.4	0.0	0.0	0.8	0.0	1.2	0.0	0.0	0.0	0.4	0.0
90	0.0	0.0	0.0	1.3	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0
89	0.0	0.0	0.0	0.4	0.0	0.0	1.3	0.0	4.8	0.4	2.2	0.0	0.0	0.0
88	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.4	0.0
87	0.0	0.0	0.0	0.4	0.0	0.0	1.5	0.4	0.8	0.0	0.0	0.4	0.0	0.0
86	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
84	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
83	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0
82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.4	0.0	0.0
81	0.0	0.0	0.0	0.0	0.4	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
78	0.0	0.0	0.4	0.9	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4
76	0.0	0.4	0.0	0.4	0.0	0.0	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4
75	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
74	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0
73	0.0	0.0	0.0	2.6	0.0	0.0	1.3	1.8	9.0	0.0	0.0	0.0	0.4	0.0

Sample							Pollen Type							
No.	27	28	29	30	31	32	33	34	35	36	37	38	39	40
72	0.0	0.4	0.0	3.9	0.0	0.0	0.0	1.8	0.9	0.0	0.0	0.0	0.0	0.0
71	0.0	0.0	0.0	2.3	0.0	0.0	1.9	1.9	1.4	0.0	0.0	0.0	0.4	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
69	0.0	0.3	0.0	1.6	0.0	0.0	0.0	0.3	0.9	0.0	0.0	0.0	0.0	0.0
68	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
67	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
66	0.0	0.0	0.0	1.5	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.4	0.4	0.0
64	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0
63	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0

Sample							Pollen Type							
No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54
108	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
107	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
106	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
105	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
104	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
103	0.8	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
102	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
101	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
99	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
98	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
97	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96	1.1	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
94	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
93	0.4	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
92	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
91	0.4	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	1.3	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
89	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sample No.	Pollen Type 41	42	43	44	45	46	47	48	49	50	51	52	53	54
88	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
87	0.0	0.0	1.2	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
86	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
84	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
83	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
82	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
81	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79	0.0	0.0	0.0	0.0	1.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	0.0	0.0	0.4	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
75	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
74	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.8	0.0	0.4	0.0	0.0	0.0	0.4	0.4	0.0	0.0
69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
66	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0

Sample No.	Pollen Type 55	56	57	58	59	60	61	62	63	64	65
108	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0
107	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
106	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
105	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0

Sample No.	Pollen Type										
	55	56	57	58	59	60	61	62	63	64	65
104	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.7
103	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
102	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
100	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
98	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
91	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.4
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0
88	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
87	0.0	0.0	0.0	0.0	0.4	0.8	0.0	1.5	0.0	0.0	0.0
86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
83	0.0	0.0	0.0	0.0	0.8	3.0	0.0	0.0	0.0	0.0	0.0
82	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.9	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0
76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	11.0	0.0
74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
73	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sample No.	Pollen Type										
	55	56	57	58	59	60	61	62	63	64	65
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
63	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.8

APPENDIX E

List of Pollen Percentages (Data Matrix) for the Upper Bluefish Alluvial Unit - each pollen type is assigned the following number:

Picea - 1
Pinus - 2
Populus - 3
Betula - 4
Salix - 5
Alnus - 6
Ericaceae - 7
Shepherdia canadensis - 8
Cyperaceae - 9
Gramineae - 10
Artemisia - 11
Chenopodiaceae-*Amaranthus* - 12
Tubuliflorae - 13
Liguliflorae - 14
Compositae:
  - *Antenaria* - 15
  - *Taraxacum* - 16

Ranunculaceae:
  - Undifferentiated - 17

Thalictrum - 18
Rosaceae:
  - *Potentilla* - 19
  - *Dryas* - 20
  - *Rubus chamaemorus* - 21
  - *Rosa acicularis* - 22
  - Undifferentiated - 23

Caryophyllaceae - 24
Polygonaceae:
  - *Bistorta* type - 25
  - *Amphibium* type - 26

Rumex-*Oxyria* - 27
Saxifraga:
  - *Oppositifolia* type - 28
  - *Hirculus* type - 29

Ribes - 30
Umbelliferae - 31
Cruiferae:
  - *Arabis* type - 32
  - Undifferentiated - 33

Onagraceae:
  - *Epilobium* - 34

Gentianaceae:
  - *Gentiana* type - 35

Labiatae:
  - *Galeopsis* type - 36
  - Undifferentiated - 37

Papaveraceae - 38
Polemonium - 39
Phlox - 40
Typha - 41

Sample No.	Grains Counted	Pollen Type												
		1	2	3	4	5	6	7	8	9	10	11	12	13
61	479	32.8	0.0	0.4	38.9	1.0	8.8	8.8	0.0	2.1	4.6	0.6	0.0	0.4
59	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	204	1.0	0.0	0.0	1.0	0.5	0.5	0.5	0.0	0.0	80.4	14.7	0.5	0.0
43	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	215	4.2	0.0	0.0	7.9	0.9	1.9	4.2	0.0	1.9	48.8	19.1	1.9	0.9
39	208	3.8	0.9	0.0	3.4	1.4	0.5	1.4	0.0	6.2	60.6	16.3	3.4	0.0
37	210	4.8	0.9	0.0	5.7	0.9	0.9	1.4	0.0	33.3	20.5	23.7	0.9	0.0
35	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	206	4.9	1.9	0.0	1.9	0.0	2.9	1.5	0.0	12.1	26.2	31.6	4.4	0.5
29	210	4.8	1.4	0.0	12.9	0.0	2.4	20.0	0.0	20.9	13.3	18.1	0.4	0.4
27	213	3.3	0.0	0.0	3.3	0.5	1.9	0.9	0.0	35.2	20.7	23.9	0.9	0.5
25	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	211	5.2	0.0	0.0	5.7	0.0	1.9	4.7	0.0	32.2	26.5	13.3	0.0	0.5
21	Sterile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	206	3.8	0.0	0.0	1.0	0.5	0.5	4.4	0.0	7.3	41.2	36.4	0.0	1.5
17	251	0.4	0.0	0.0	1.2	0.8	0.0	0.0	0.0	5.2	51.7	35.5	0.0	0.8
15	268	2.6	0.0	0.0	0.4	0.4	0.0	0.4	0.0	8.9	36.2	38.8	1.1	1.9
13	203	0.9	0.0	0.0	1.5	0.0	0.5	1.9	0.0	7.4	32.5	41.4	4.4	0.0
11	202	0.0	0.0	0.0	3.0	4.9	1.9	0.0	0.0	27.2	32.2	15.8	1.9	1.0
9	218	0.0	0.5	0.0	3.2	2.8	0.5	0.5	0.9	19.7	38.1	17.4	0.9	1.4
7	211	0.9	0.0	0.0	1.4	3.8	1.4	0.0	0.0	18.0	41.2	24.6	0.9	0.5
5	210	0.5	0.0	0.0	1.4	2.4	0.9	1.4	0.0	20.9	43.3	16.7	0.9	0.5
3	215	2.3	0.0	0.0	3.3	0.9	1.4	0.9	0.5	29.8	23.3	21.9	3.7	0.0
1	209	0.0	0.5	0.0	3.8	5.7	1.4	0.0	0.9	35.9	23.4	19.1	0.0	0.0

Sample No.	Pollen Type 14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
61	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	7.4	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.5	0.0	0.0	0.0	0.0
37	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.4
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.9	8.3	0.0	0.0	0.0	0.0
29	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	1.5	0.5
27	4.6	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
23	3.3	0.5	2.3	0.0	0.0	0.5	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
19	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
15	1.9	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
13	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	1.9	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.5	1.9	0.0	0.5	0.0	0.0
9	3.7	0.0	0.0	0.0	0.0	1.8	1.8	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.5
7	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0
5	2.4	0.0	0.0	0.0	0.0	0.0	1.4	0.9	0.0	0.0	1.4	0.0	0.0	0.0	0.0
3	2.3	0.0	0.0	0.0	0.5	1.4	0.0	0.0	0.0	0.9	0.5	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.5	0.9	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0

	Pollen Type												
Sample No.	29	30	31	32	33	34	35	36	37	38	39	40	41
61	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.9	0.0
37	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.4	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
19	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
15	0.4	0.0	0.0	4.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0
13	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.1	0.0
11	0.0	0.0	0.0	3.0	0.0	0.0	0.5	0.0	0.0	1.0	1.0	0.5	0.0
9	0.5	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.5	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0
5	1.4	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.9	0.9	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0
1	0.0	0.5	0.0	3.8	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0

APPENDIX F

Factor Analysis Results for
the
Lower Bluefish Alluvial Unit

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CORRELATION COEFFICIENTS..

            ARBOREAL      BET       SAL       ALN      ERIC      CORY    SHRUBS     CYPER    GRAMIN     ARTEM
ARBOREAL    1.00000   0.12151  -0.22824  -0.47854   0.18047   0.49739  -0.22143  -0.10083  -0.44213  -0.50172
BET         0.12151   1.00000  -0.36790  -0.05053   0.23740   0.35364  -0.08806  -0.81691  -0.12747  -0.33523
SAL        -0.22824  -0.36790   1.00000  -0.08766  -0.37317   0.03921   0.08668   0.30144  -0.11154   0.15937
ALN        -0.47854  -0.05053  -0.08766   1.00000   0.05814  -0.35484  -0.25788  -0.31786   0.65869  -0.15749
ERIC        0.18047   0.23740  -0.37317   0.05814   1.00000   0.42540  -0.04556  -0.51272   0.06858  -0.33982
CORY        0.49739   0.35364   0.03921  -0.35484   0.42540   1.00000  -0.19801  -0.42160  -0.35021  -0.41735
SHRUBS     -0.22143  -0.08806   0.08668  -0.25788  -0.04556  -0.19801   1.00000   0.18571  -0.26729   0.36952
CYPER      -0.10083  -0.81691   0.30144  -0.31786  -0.51272  -0.42160   0.18571   1.00000  -0.13773   0.45090
GRAMIN     -0.44213  -0.12747  -0.11154   0.65869   0.06858  -0.35021  -0.26729  -0.13773   1.00000  -0.01926
ARTEM      -0.50172  -0.33523   0.15937  -0.15749  -0.33982  -0.41735   0.36952   0.45090  -0.01926   1.00000
HERBS      -0.23868   0.22050   0.29790  -0.31148  -0.02032   0.19401   0.46011  -0.14727  -0.39258   0.27176

            HERBS
ARBOREAL   -0.23868
BET         0.22050
SAL         0.29790
ALN        -0.31148
ERIC       -0.02032
CORY        0.19401
SHRUBS      0.46011
CYPER      -0.14727
GRAMIN     -0.39258
ARTEM       0.27176
HERBS       1.00000

DETERMINANT OF CORRELATION MATRIX =  0.0001727( 0.17265260E-03)
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INVERSE OF CORRELATION MATRIX..

            ARBOREAL    BET        SAL        ALN        ERIC       CORY       SHRUBS     CYPER      GRAMIN     ARTEM

ARBOREAL    18.47984   26.43564    6.64921   20.98428    9.40757    2.77611    1.87147   32.33379    6.73939    7.61902
BET         26.43564   47.19652   11.12686   34.22025   16.39380    5.71692    2.94693   56.86436   10.21455   11.29121
SAL          6.64920   11.12685    4.28132    7.78119    4.41244    0.62408    0.74467   12.60835    2.36148    2.94007
ALN         20.98428   34.22023    7.78119   28.36862   11.94161    5.17404    2.46552   42.73288    6.92441    9.05201
ERIC         9.40757   16.39380    4.41244   11.94160    7.48725    1.17728    0.66220   20.17847    3.30338    4.11537
CORY         2.77611    5.71691    0.62408    5.17404    1.17728    3.48365    0.98599    7.88898    1.54239    1.70833
SHRUBS       1.87147    2.94693    0.74467    2.46552    0.66220    0.98599    1.84970    3.42184    0.94831    0.61887
CYPER       32.33380   56.86436   12.60836   42.73289   20.17848    7.88899    3.42184   71.40167   12.66043   13.14894
GRAMIN       6.73939   10.21454    2.36148    6.92440    3.30338    1.54239    0.94831   12.66043    4.57134    2.46430
ARTEM        7.61902   11.29120    2.94007    9.05200    4.11537    1.70833    0.61886   13.14893    2.46430    4.94095
HERBS        7.26556   10.43101    1.89268    8.63729    3.80483    1.02518    0.02214   13.95044    3.13054    2.30103


            HERBS

ARBOREAL     7.26556
BET         10.43100
SAL          1.89268
ALN          8.63729
ERIC         3.80483
CORY         1.02518
SHRUBS       0.02214
CYPER       13.95044
GRAMIN       3.13054
ARTEM        2.30103
HERBS        5.08699
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VARIABLE   EST COMMUNALITY                     FACTOR        EIGENVALUE   PCT OF VAR   CUM PCT

ARBOREAL         1.00000                          1            3.20533       29.1         29.1
BET              1.00000                          2            2.53512       23.0         52.2
SAL              1.00000                          3            1.72354       15.7         67.9
ALN              1.00000                          4            1.09353        9.9         77.8
ERIC             1.00000                          5            0.83134        7.6         85.4
CORY             1.00000                          6            0.57333        5.2         90.6
SHRUBS           1.00000                          7            0.33363        3.0         93.6
CYPER            1.00000                          8            0.25834        2.3         95.9
GRAMIN           1.00000                          9            0.23137        2.1         98.1
ARTEM            1.00000                         10            0.20876        1.9         99.9
HERBS            1.00000                         11            0.00568        0.1        100.0
     FACTOR MATRIX USING PRINCIPAL FACTOR, NO ITERATIONS


               FACTOR  1   FACTOR  2   FACTOR  3   FACTOR  4   FACTOR  5   FACTOR  6

ARBOREAL        0.57069     0.38446    -0.62296    -0.12943    -0.05125    -0.12390
BET             0.70169     0.05956     0.48164    -0.05159    -0.47035     0.03127
SAL            -0.44983     0.27405    -0.00322     0.79048     0.13375    -0.11150
ALN            -0.03101    -0.86609     0.22886     0.18350     0.04200    -0.20311
ERIC            0.63125    -0.09355     0.17495    -0.21652     0.67162     0.10713
CORY            0.69229     0.42979    -0.06476     0.33136     0.23501     0.21279
SHRUBS         -0.36659     0.44388     0.46000    -0.37601     0.22473    -0.44885
CYPER          -0.78871     0.21248    -0.50885    -0.11641     0.09626     0.02729
GRAMIN         -0.11652    -0.86021     0.10596     0.06712     0.14427     0.10277
ARTEM          -0.72728     0.16800     0.28188    -0.23971    -0.01579     0.48238
HERBS          -0.08560     0.59563     0.67464     0.20500     0.02656     0.03322


                          VARIABLE       COMMUNALITY

                          ARBOREAL         0.89631
                          BET              0.95276
                          SAL              0.93265
                          ALN              0.88014
                          ERIC             0.94727
                          CORY             0.87848
                          SHRUBS           0.93637
                          CYPER            0.94970
                          GRAMIN           0.80064
                          ARTEM            0.92701
                          HERBS            0.86107
```

VARIMAX ROTATED FACTOR MATRIX

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
ARBOREAL	0.65505	-0.02625	-0.58126	0.13090	-0.23192	-0.24030
BET	0.11772	0.94834	-0.07840	0.02863	-0.02457	-0.17885
SAL	0.01526	-0.25172	0.02547	-0.16992	0.01777	0.91609
ALN	-0.91597	0.09868	-0.15489	-0.02429	-0.08170	-0.01172
ERIC	-0.06081	0.16040	-0.13587	0.92030	0.05647	-0.22191
CORY	0.49597	0.32716	-0.22843	0.56393	-0.27608	0.28114
SHRUBS	0.13570	-0.08943	0.17060	-0.01136	0.93820	0.02228
CYPER	0.20106	-0.85418	0.21642	-0.35564	0.06047	0.05171
GRAMIN	-0.84041	-0.08028	0.07117	0.08334	-0.24610	-0.12382
ARTEM	0.03042	-0.26761	0.88823	-0.19171	0.16960	0.00094
HERBS	0.28201	0.39389	0.39599	0.08267	0.46837	0.49334

TRANSFORMATION MATRIX

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
FACTOR 1	0.19538	0.61307	-0.48628	0.48375	-0.26110	-0.21752
FACTOR 2	0.89704	0.02172	0.10773	0.01874	0.31932	0.28446
FACTOR 3	-0.30977	0.62583	0.44863	0.13809	0.51065	0.17684
FACTOR 4	-0.13687	0.10959	-0.17521	-0.05068	-0.36061	0.89775
FACTOR 5	-0.13718	-0.46770	-0.01857	0.82656	0.22416	0.16926
FACTOR 6	0.15372	0.03542	0.72085	0.24657	-0.62354	-0.07675

FACTOR SCORE COEFFICIENTS

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
ARBOREAL	0.27422	-0.10555	-0.36629	-0.05918	-0.01902	-0.15961
BET	0.06974	0.57097	0.07954	-0.30687	-0.05078	-0.13382
SAL	-0.08077	-0.08777	-0.19077	-0.01773	-0.03313	0.75205
ALN	-0.43383	0.05196	-0.25824	-0.04684	0.13295	0.11479
ERIC	-0.08107	-0.20947	0.10018	0.83245	0.12461	-0.09074
CORY	0.18271	0.02672	0.10558	0.41227	-0.29877	0.28599
SHRUBS	-0.05832	-0.09113	-0.31491	0.03264	0.89481	-0.08096
CYPER	0.12457	-0.39792	0.04705	-0.04540	-0.02509	-0.05446
GRAMIN	-0.33517	-0.05927	0.12394	0.16908	-0.16247	-0.00702
ARTEM	0.12640	-0.02065	0.83609	0.11693	-0.28592	-0.16745
HERBS	0.06316	0.24134	0.22223	0.07673	0.18531	0.31111

APPENDIX G

Factor Analysis Results for the Upper Bluefish Alluvial Unit

```
CORRELATION COEFFICIENTS..


              PICEA       BET        SAL        ALN        ERIC       CYPER      GRAM       ARTEM      HERBS

PICEA        1.00000    0.95792   -0.03385    0.92578    0.48975    0.02694   -0.01468   -0.00110    0.02989
BET          0.95792    1.00000    0.08479    0.93642    0.61517    0.11093   -0.01802   -0.03576    0.06038
SAL         -0.03385    0.08479    1.00000    0.18748   -0.12689    0.56298    0.37410    0.24780    0.46536
ALN          0.92578    0.93642    0.18748    1.00000    0.52969    0.24342    0.04596    0.07327    0.24740
ERIC         0.48975    0.61517   -0.12689    0.52969    1.00000    0.17530    0.02760    0.13444    0.07636
CYPER        0.02694    0.11093    0.56298    0.24342    0.17530    1.00000    0.27498    0.47128    0.68373
GRAM        -0.01468   -0.01802    0.37410    0.04596    0.02760    0.27498    1.00000    0.69050    0.53772
ARTEM       -0.00110   -0.03576    0.24780    0.07327    0.13444    0.47128    0.69050    1.00000    0.73864
HERBS        0.02989    0.06038    0.46536    0.24740    0.07636    0.68373    0.53772    0.73864    1.00000

DETERMINANT OF CORRELATION MATRIX =  0.0000538( 0.53767726E-04).



INVERSE OF CORRELATION MATRIX..


              PICEA       BET        SAL        ALN        ERIC       CYPER      GRAM       ARTEM      HERBS

PICEA       50.01135  -38.61600    9.09135  -18.69263   10.95533   -0.34204   -0.91545   -8.17659    7.15926
BET        -38.61598   43.49814   -7.43348    2.19603  -10.72604    0.82035    0.23100    6.43523   -3.17526
SAL          9.09135   -7.43348    3.64799   -3.41650    2.65671   -1.17096   -0.94600   -0.83610    1.04862
ALN        -18.69264    2.19604   -3.41650   19.60681   -3.05089   -0.15173    0.86807    3.38899   -5.46784
ERIC        10.95531  -10.72604    2.65671   -3.05088    4.48341   -0.74230   -0.23434   -2.18570    1.74417
CYPER       -0.34203    0.82035   -1.17096   -0.15174   -0.74230    2.60450    0.66298   -0.26315   -1.34306
GRAM        -0.91545    0.23101   -0.94600    0.86807   -0.23434    0.66298    2.31486   -1.40120   -0.40626
ARTEM       -8.17659    6.43523   -0.83610    3.38898   -2.18570   -0.26315   -1.40120    4.82165   -3.05464
HERBS        7.15925   -3.17527    1.04862   -5.46782    1.74417   -1.34307   -0.40626   -3.05464    5.10227
```

```
VARIABLE   EST COMMUNALITY              FACTOR      EIGENVALUE   PCT OF VAR   CUM PCT

PICEA           1.00000                    1          3.49352       38.8        38.8
BET             1.00000                    2          2.86496       31.8        70.6
SAL             1.00000                    3          0.99991       11.1        81.8
ALN             1.00000                    4          0.72884        8.1        89.9
ERIC            1.00000                    5          0.47871        5.3        95.2
CYPER           1.00000                    6          0.20735        2.3        97.5
GRAM            1.00000                    7          0.17581        2.0        99.4
ARTEM           1.00000                    8          0.04045        0.4        99.9
HERBS           1.00000                    9          0.01044        0.1       100.0


FACTOR MATRIX USING PRINCIPAL FACTOR, NO ITERATIONS


             FACTOR  1   FACTOR  2   FACTOR  3   FACTOR  4   FACTOR  5     VARIABLE     COMMUNALITY

PICEA         0.75744    -0.58031     0.02099     0.21542    -0.15839     PICEA           0.98239
BET           0.80858    -0.56084    -0.06053     0.10498     0.01829     BET             0.98338
SAL           0.38725     0.52342    -0.63390     0.20452     0.31163     SAL             0.96470
ALN           0.87265    -0.41116    -0.12671     0.10983    -0.11677     ALN             0.97233
ERIC          0.59936    -0.35118     0.34340    -0.47418     0.40340     ERIC            0.98805
CYPER         0.54719     0.54892    -0.33916    -0.44048    -0.05229     CYPER           0.91252
GRAM          0.38393     0.63315     0.37450     0.43182     0.27271     GRAM            0.94937
ARTEM         0.46500     0.68539     0.45172    -0.00001    -0.14105     ARTEM           0.90993
HERBS         0.57644     0.68949     0.02607    -0.11043    -0.28777     HERBS           0.90337
```

```
VARIMAX ROTATED FACTOR MATRIX


              FACTOR  1  FACTOR  2  FACTOR  3  FACTOR  4  FACTOR  5

PICEA          0.98325   -0.03055    0.01297   -0.07592    0.09352
BET            0.95378   -0.00667   -0.03083    0.07276    0.25961
SAL            0.05837    0.29966    0.17815    0.90943   -0.11265
ALN            0.95524    0.17165    0.00940    0.10539    0.13848
ERIC           0.41635    0.08536    0.04788   -0.10857    0.89069
CYPER          0.04191    0.84721    0.04710    0.39923    0.17719
GRAM          -0.01185    0.09464    0.93764    0.24613    0.02279
ARTEM         -0.01917    0.56562    0.75963   -0.09786    0.05494
HERBS          0.09603    0.80951    0.46553    0.12699   -0.07746


TRANSFORMATION MATRIX


              FACTOR  1  FACTOR  2  FACTOR  3  FACTOR  4  FACTOR  5

FACTOR  1      0.76899    0.43452    0.31433    0.20639    0.28006
FACTOR  2     -0.53939    0.54051    0.53874    0.30350   -0.18590
FACTOR  3     -0.07697   -0.15793    0.59496   -0.71729    0.31724
FACTOR  4      0.27055   -0.53416    0.47617    0.21507   -0.60703
FACTOR  5     -0.19645   -0.45690    0.17391    0.55183    0.64644

FACTOR SCORE COEFFICIENTS


              FACTOR  1  FACTOR  2  FACTOR  3  FACTOR  4  FACTOR  5

PICEA          0.41932   -0.02529    0.05471   -0.15080   -0.28826
BET            0.31970   -0.09007    0.00651    0.08384    0.01927
SAL           -0.01647   -0.20029    0.00292    0.95264    0.04645
ALN            0.36794    0.08194   -0.04485   -0.00330   -0.19272
ERIC          -0.16995   -0.08345    0.02898    0.07696    1.11944
CYPER         -0.09884    0.59792   -0.35612    0.14353    0.19689
GRAM          -0.01514   -0.46871    0.75762    0.26289    0.11713
ARTEM         -0.00358    0.25042    0.38825   -0.38655   -0.05434
HERBS          0.07217    0.55325    0.02034   -0.27591   -0.28688
```

APPENDIX H

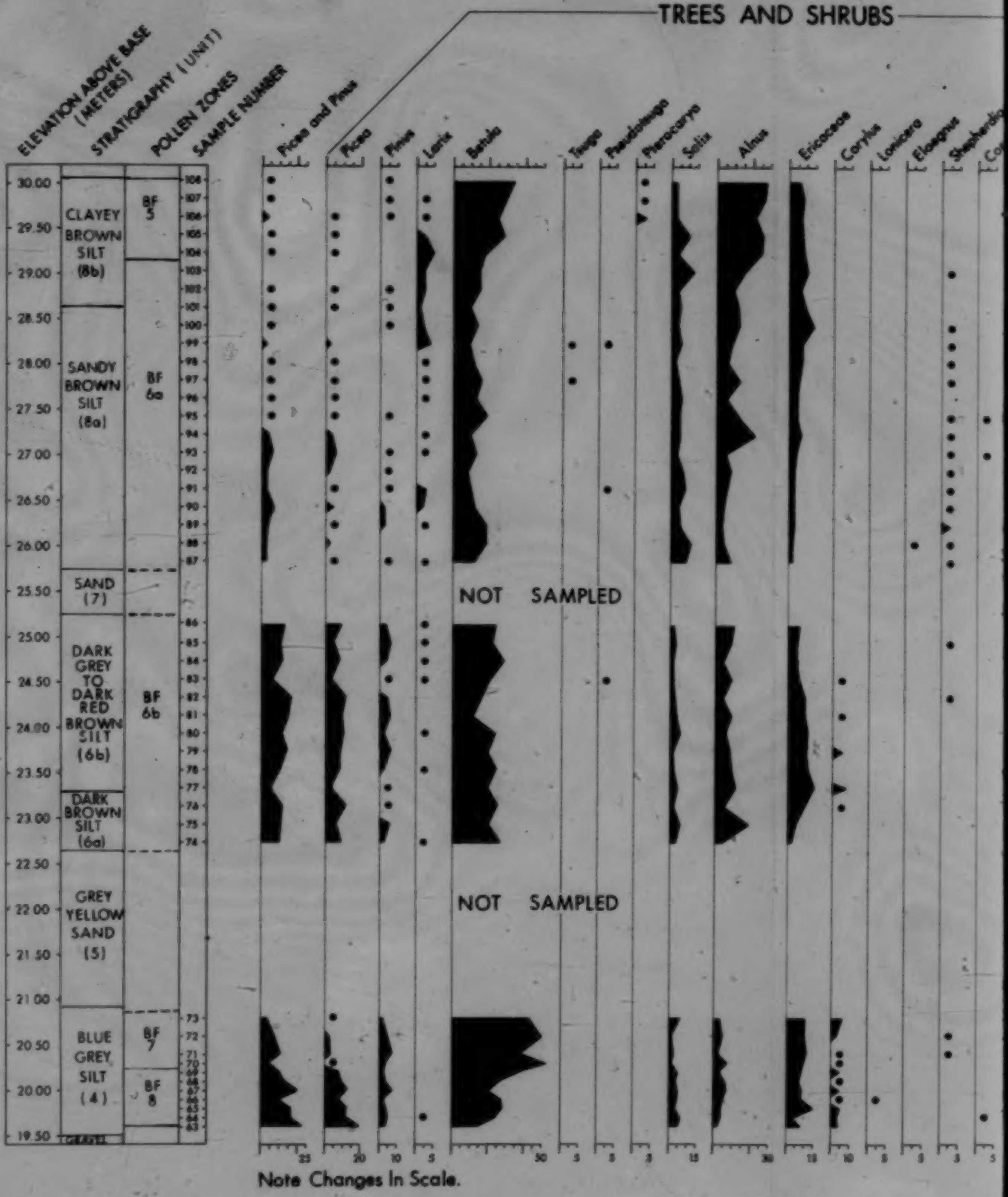
Factor Scores for the Lower Bluefish Alluvial Unit

FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	SAMPLE NO.
-2.231	1.588	-0.267	-0.541	-0.625	-0.232	108
-2.782	1.199	-0.459	0.204	-0.108	-0.158	107
-1.872	0.518	-0.735	-0.015	0.006	-0.509	106
-2.164	0.923	-0.710	-0.327	-0.547	0.501	105
-1.553	-0.134	-0.888	-0.008	-0.253	0.014	104
-1.433	-0.633	-0.734	-0.150	0.232	1.415	103
-0.129	-0.649	1.156	-0.161	-0.996	-0.413	102
-0.808	-1.031	0.824	0.880	-0.724	0.362	101
-1.101	-0.927	1.149	2.062	0.161	-0.380	100
0.153	-1.098	0.897	0.244	0.096	0.409	99
-0.168	-1.092	2.117	0.563	0.392	-1.269	98
-0.554	-0.878	-0.298	-0.499	1.573	-0.776	97
0.172	-0.661	2.668	-0.196	-1.486	0.536	96
-0.312	-0.273	1.403	-0.559	-0.379	-0.154	95
-1.104	-0.444	1.012	0.264	0.134	0.302	94
0.730	-0.837	0.502	-0.729	1.991	-0.807	93
-0.069	-1.235	0.467	-0.641	1.006	0.842	92
-0.062	-0.842	0.025	-0.852	0.520	1.501	91
0.439	-0.825	1.455	-0.779	-0.448	-0.395	90
0.845	0.406	0.917	-0.837	2.554	0.799	89
0.189	-0.127	0.739	-1.247	-0.226	2.642	88
0.260	-0.560	0.171	-1.368	0.187	2.016	87
-0.033	0.077	-0.829	-0.640	-0.341	-1.307	86
0.537	-0.275	-1.096	-1.226	0.288	-0.981	85
0.549	0.208	-0.272	-1.192	-0.931	-1.412	84
0.236	0.012	0.202	-0.217	-0.229	-0.575	83
0.846	-0.831	-1.288	0.209	1.916	-1.307	82
0.536	-1.047	-0.865	0.651	-0.619	-0.292	81
0.285	-0.394	-1.268	0.430	1.279	-0.191	80
0.548	-0.364	-0.489	0.880	-0.854	-0.974	79
-0.136	0.045	-0.835	0.627	1.250	-0.932	78
-0.731	-0.312	-0.560	2.746	0.419	0.614	77
0.521	0.018	-0.056	0.322	0.227	-1.223	76
-0.241	0.345	-1.505	-1.329	-0.290	0.637	75
0.560	0.118	-0.696	-2.298	-1.070	-0.532	74
1.034	2.688	0.237	1.466	1.641	2.691	73
0.915	2.787	1.336	0.281	-0.490	-0.668	72
0.869	1.535	0.217	0.424	1.628	-0.665	71
0.427	2.734	1.562	-0.089	-0.079	-1.485	70
1.427	1.041	-0.501	0.306	-1.387	0.889	69
0.485	0.251	0.028	-0.311	-1.218	-0.532	68
1.217	0.009	-1.094	1.017	-1.322	0.668	67
0.139	0.209	-0.750	0.045	0.560	0.081	66
0.885	-0.616	-0.476	2.683	-1.275	0.112	65
0.975	-0.041	-1.106	-0.849	-1.104	0.581	64
1.705	-0.586	-1.307	0.757	-1.055	0.558	63

APPENDIX I

Factor Scores for the Upper Bluefish Alluvial Unit

FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	SAMPLE NO.
5.154	-0.993	-0.578	0.099	-0.221	61
-0.418	-0.668	-0.871	-0.283	-0.233	59
-0.418	-0.668	-0.871	-0.283	-0.233	57
-0.418	-0.668	-0.871	-0.283	-0.233	55
-0.418	-0.668	-0.871	-0.283	-0.233	53
-0.418	-0.668	-0.871	-0.283	-0.233	51
-0.418	-0.668	-0.871	-0.283	-0.233	49
-0.418	-0.668	-0.871	-0.283	-0.233	47
-0.262	-2.041	2.314	0.506	0.119	45
-0.418	-0.668	-0.871	-0.283	-0.233	43
0.540	-0.413	1.362	-0.125	0.243	41
0.004	-1.135	1.556	0.668	0.079	39
0.111	1.375	-0.360	-0.133	0.046	37
-0.419	-0.668	-0.871	-0.283	-0.233	35
-0.419	-0.668	-0.871	-0.283	-0.233	33
0.664	1.548	0.626	-1.585	-0.979	31
0.037	0.351	-0.326	-0.226	5.079	29
0.156	1.823	-0.439	-0.476	-0.237	27
-0.418	-0.668	-0.871	-0.283	-0.233	25
0.266	1.368	-0.409	-0.432	0.746	23
-0.418	-0.668	-0.871	-0.283	-0.233	21
-0.233	-0.290	1.443	-0.623	0.774	19
-0.368	-0.523	1.789	-0.334	-0.257	17
-0.199	0.708	1.292	-1.192	-0.625	15
-0.182	1.004	1.270	-1.597	-0.338	13
0.015	0.953	-0.064	2.439	-0.460	11
-0.210	0.834	0.435	0.995	-0.379	9
-0.102	0.055	0.748	1.742	-0.315	7
-0.261	0.484	0.545	0.996	0.025	5
0.084	1.954	-0.232	-0.442	-0.465	3
-0.197	0.953	-0.518	3.113	-0.037	1


TREES AND SHRUBS
ELEVATION ABOVE BASE (METERS)
STRATIGRAPHY (UNIT)
POLLEN ZONES
SAMPLE NUMBER
Picea and Pinus
Picea
Pinus
Larix
Betula
Tsuga
Pseudotsuga
Pterocarya
Salix
Alnus
Ericaceae
Corylus
Lonicera
Elaeagnus
30.00
29.50
29.00
28.50
28.00
27.50
27.00
26.50
26.00
25.50
25.00
24.50
24.00
23.50
23.00
22.50
22.00
21.50
21.00
20.50
20.00
19.50
CLAYEY BROWN SILT (8b)
SANDY BROWN SILT (8a)
SAND (7)
DARK GREY TO DARK RED BROWN SILT (6b)
DARK BROWN SILT (6a)
GREY YELLOW SAND (5)
BLUE GREY SILT (4)
GRAVEL
BF 5
BF 6a
BF 6b
BF 7
BF 8
108
107
106
105
104
103
102
101
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
85
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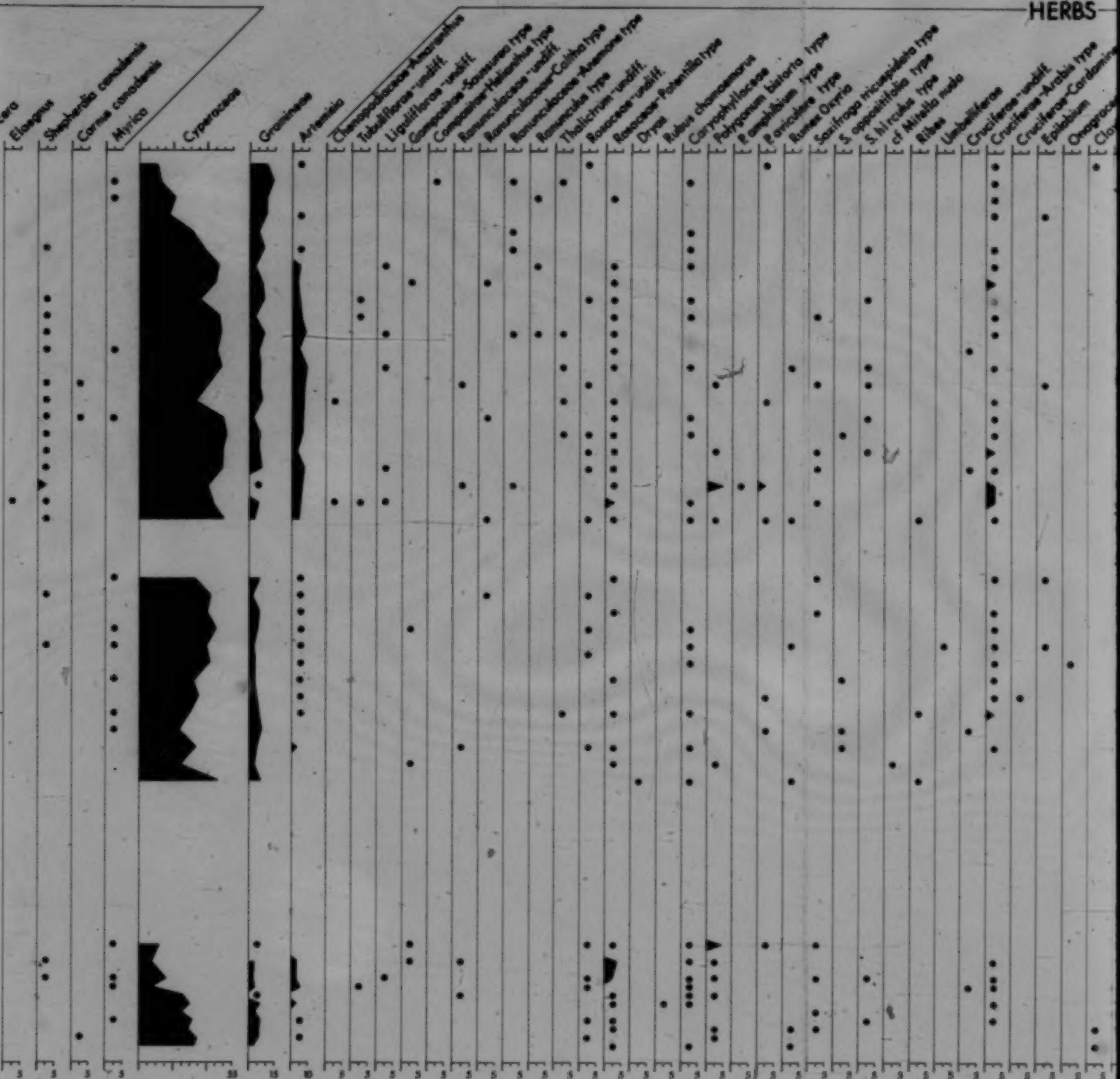
83
82
81
80
79
78
77
76
75
74
73
72
71
70
69
68
67
66
65
64
63
NOT SAMPLED
NOT SAMPLED
25
20
10
5
50
5
5
5
15
30
15
10
5
5
3
5
Note Changes In Scale.

17

FIGURE 5: RELATIVE PERCENT POLLEN DIAGRAM - LO

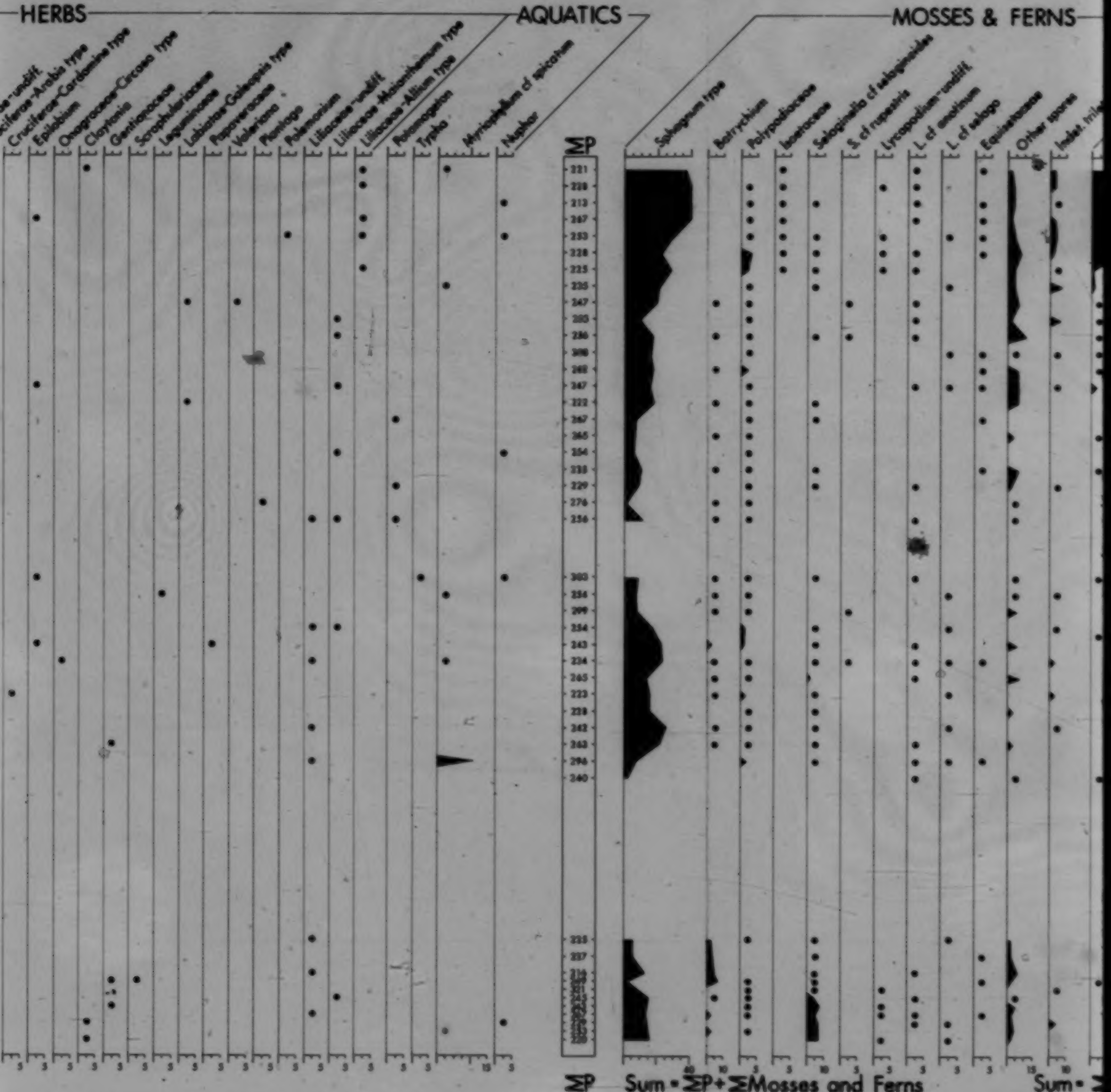
STATION HH 75-24, BLUEFISH RIVER, YUKON TERRITORY,



2 of

AM - LOWER BLUEFISH UNIT

ERRITORY, CANADA



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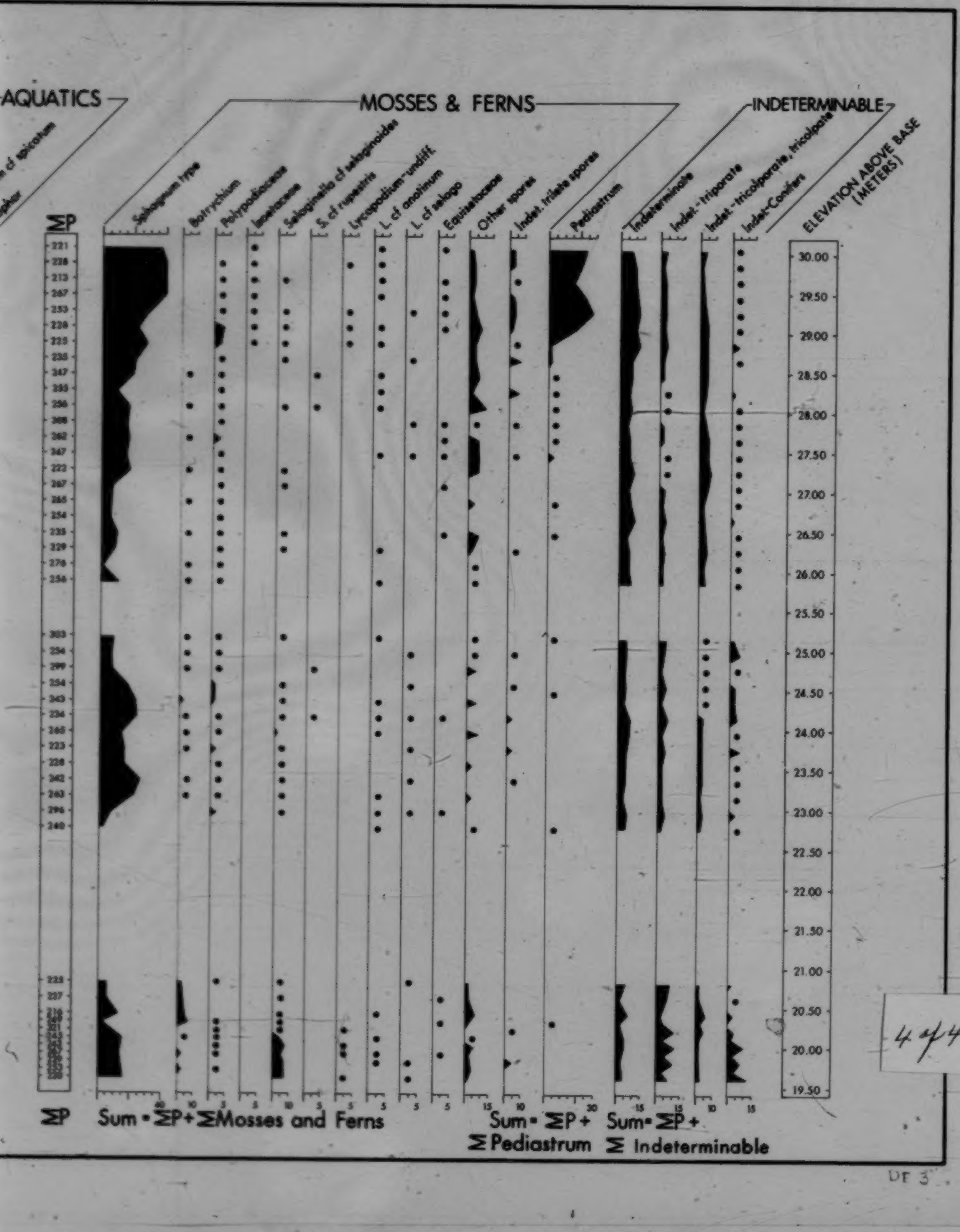
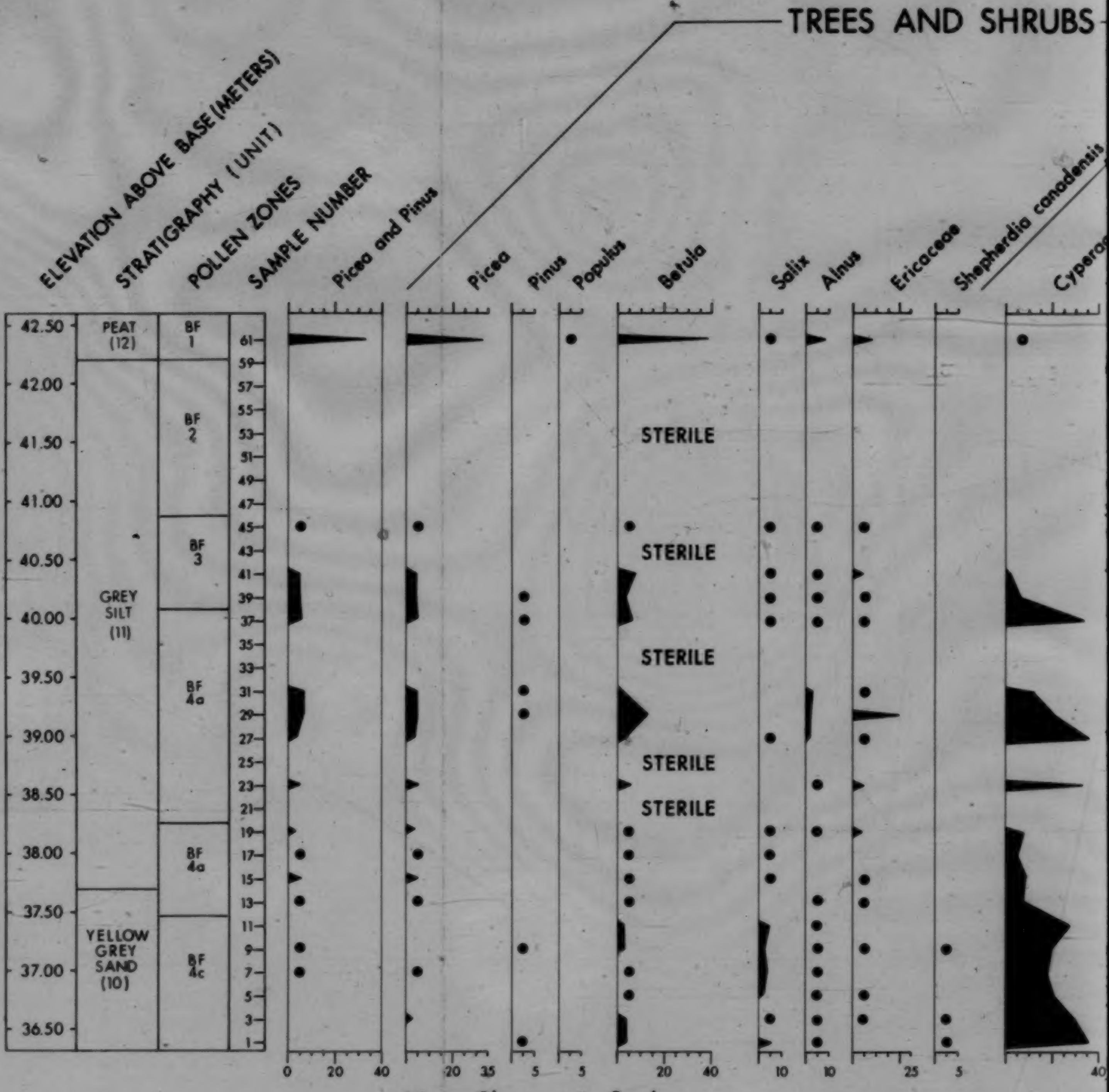


AQUATICS
...m cf spicatum
...phar
MOSSES & FERNS
INDETERMINABLE
ΣP
Sphagnum type
Botrychium
Polypodiaceae
Isoetaceae
Selaginella cf selaginoides
S. cf rupestris
Lycopodium-undiff.
L. cf annotinum
L. cf selago
Equisetaceae
Other spores
Indet. trilete spores
Pediastrum
Indeterminate
Indet.-triporate
Indet.-tricolporate, tricolpate
Indet.-Conifers
ELEVATION ABOVE BASE (METERS)
30.00
29.50
29.00
28.50
28.00
27.50
27.00
26.50
26.00
25.50
25.00
24.50
24.00
23.50
23.00
22.50
22.00
21.50
21.00
20.50
20.00
19.50
ΣP
Sum = ΣP + ΣMosses and Ferns
Sum = ΣP + ΣPediastrum
Sum = ΣP + Σ Indeterminable

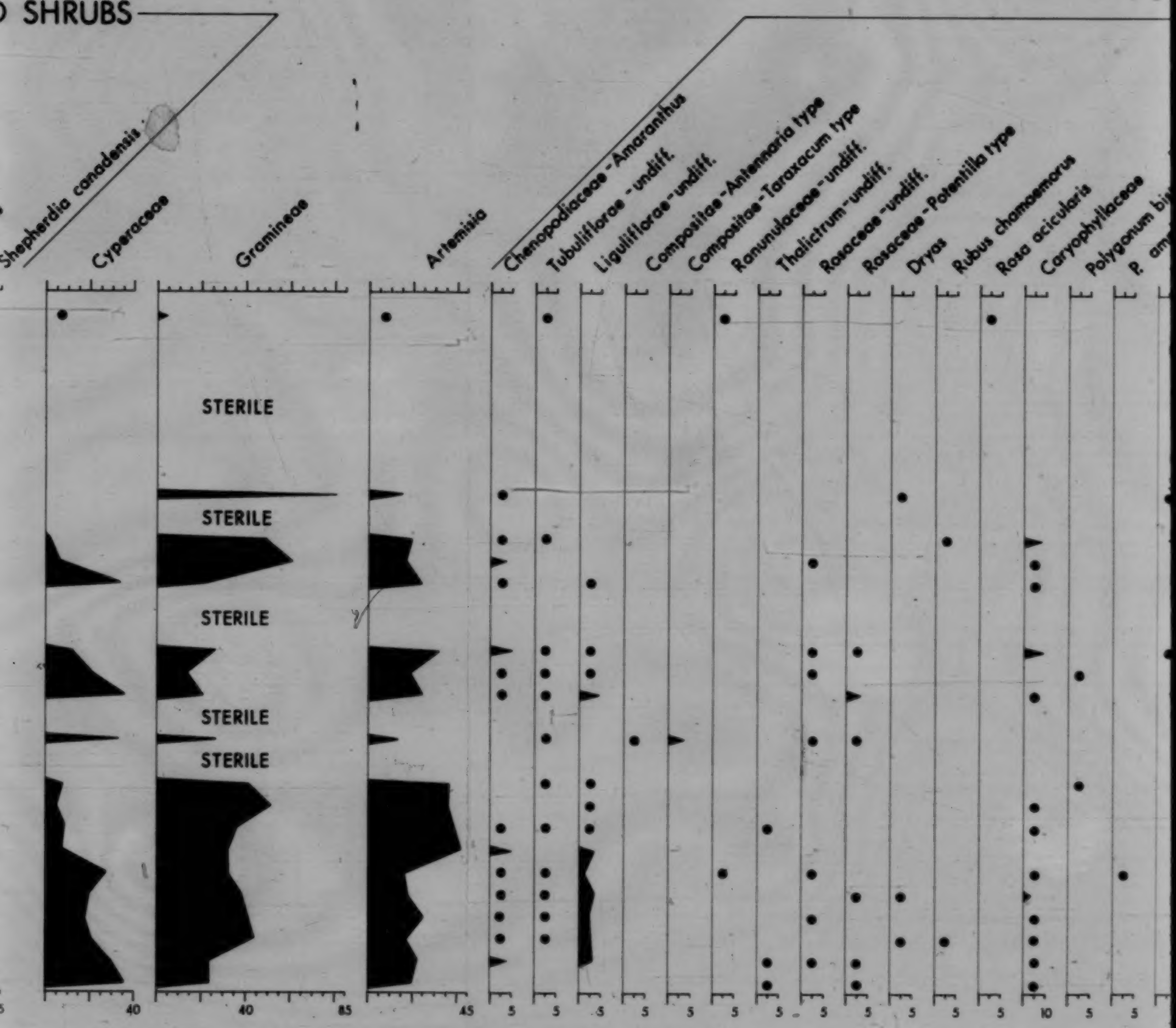
4 of 4

DF 3



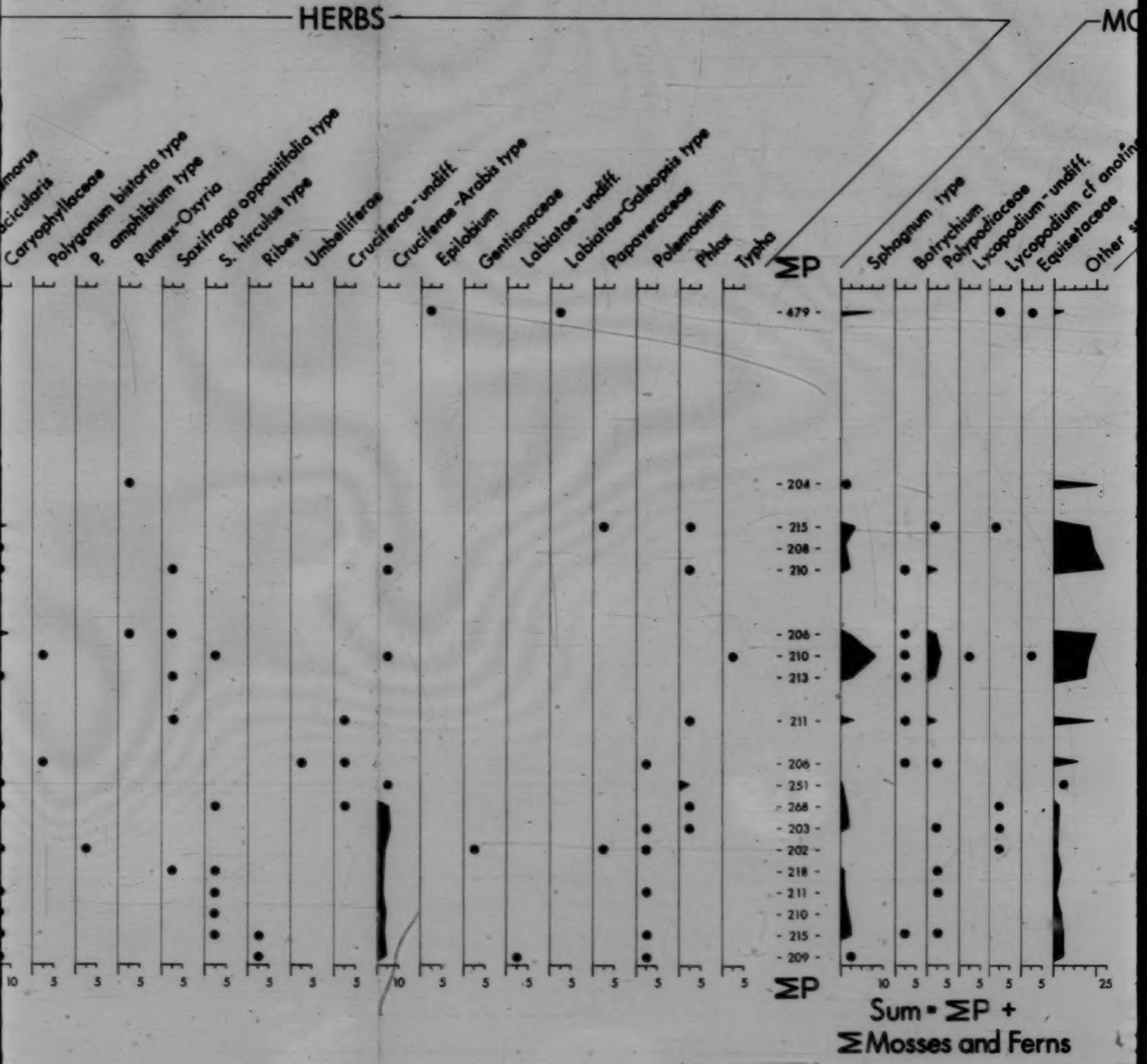
Note Changes In Scale.

FIGURE 6: RELATIVE PERCENT POLLEN DIAG
STATION HH 75-24, BLUEFISH RIVER, YUKO

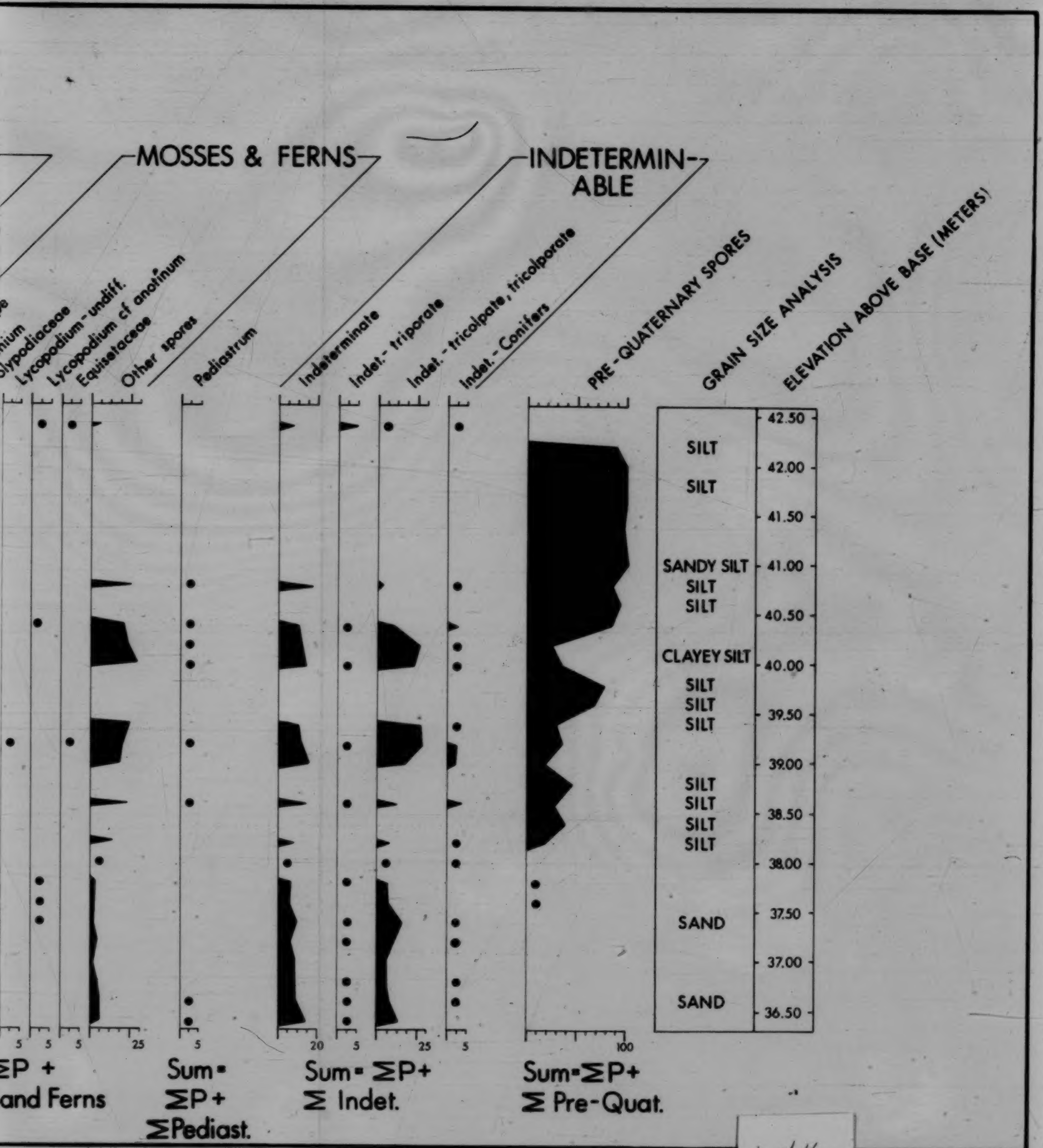


2 of

N DIAGRAM - UPPER BLUEFISH UNIT
ER, YUKON TERRITORY, CANADA



3 of

MOSSES & FERNS
INDETERMINABLE
Lycopodium - undiff.
Lycopodium cf annotinum
Equisetaceae
Other spores
Pediastrum
Indeterminate
Indet. - triporate
Indet. - tricolpate, tricolporate
Indet. - Conifers
PRE-QUATERNARY SPORES
GRAIN SIZE ANALYSIS
ELEVATION ABOVE BASE (METERS)
SILT
SILT
SANDY SILT
SILT
SILT
CLAYEY SILT
SILT
SILT
SILT
SILT
SILT
SILT
SILT
SAND
SAND
42.50
42.00
41.50
41.00
40.50
40.00
39.50
39.00
38.50
38.00
37.50
37.00
36.50
5
5
5
25
5
20
5
25
5
100
ΣP +
and Ferns
Sum = ΣP + ΣPediast.
Sum = ΣP + Σ Indet.
Sum = ΣP + Σ Pre-Quat.
DE-3